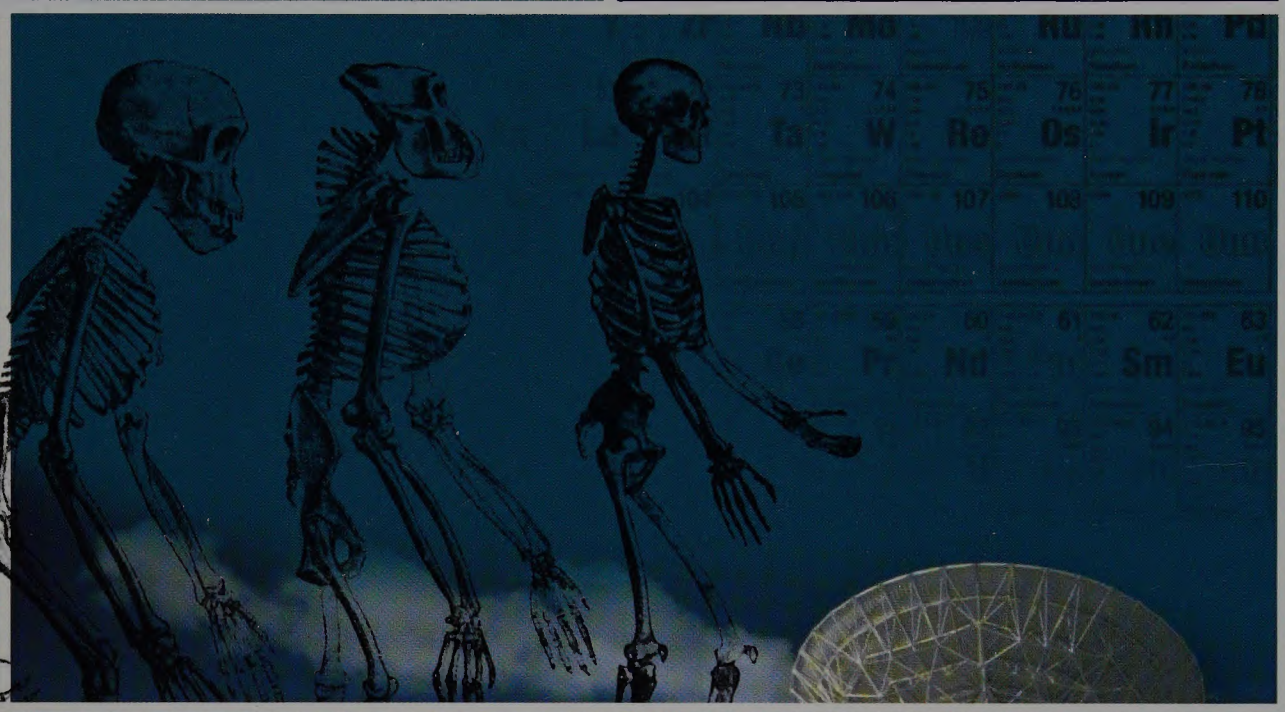
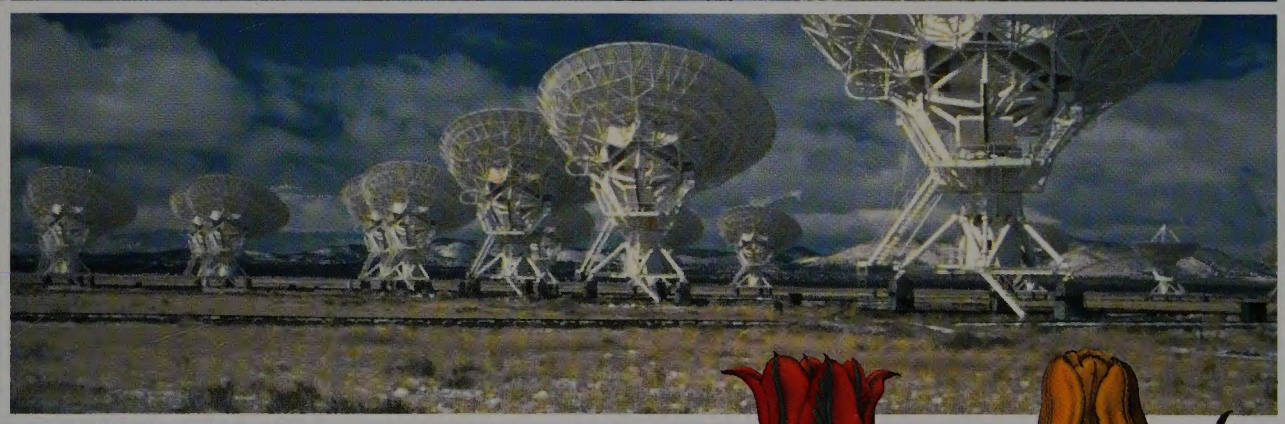
SCIENTIFIC THOUGHT

{ IN CONTEXT }





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Tulipa parte media viridibus signaturis altera vero rubra.
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BRENDA WILMOTH LERNER AND K. LEE LERNER

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Scientific Thought: In Context

Scientific Thought: In Context

K. Lee Lerner & Brenda Wilmoth Lerner, Editors

VOLUME 3

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Introduction

Written by a global array of experts in science, history, sociology, and law, *Scientific Thought: In Context* is intended to introduce to younger students (especially those just beginning their study of biology, chemistry, physics, earth science, etc.) insight into the power of science and a hint of the richness and complexity of scientific thought.

At the core of scientific thought is the assertion that the laws of physics and chemistry are the same throughout the universe. Although humans now understand some of the key laws that shape the cosmos, other laws—and the multitude of manifestations that evolve from them—remain shrouded in wonderful mystery to be peeled back by future generations. Such is the power of science's self-corrective mechanisms that, far above differences in culture and regardless of the language used to describe those laws or the social station of the eye viewing them (or whatever has evolved to be something akin to an eye in that part of the universe), ultimately the laws of science will be found to be the same.

These assertions regarding science and scientific thought do not, however, diminish value in the study of science as a cultural phenomena and manifestation. It is also true that students and other readers just beginning to explore the laws of biology and chemistry often have far less exposure to formal philosophical thought than to hard science. Accordingly, *Scientific Thought: In Context* is not intended to be a comprehensive history of science or to deeply explore the philosophy of science. Mindful of its audience, *Scientific Thought: In Context* only attempts to stab a toe, perhaps in some places to wade ankle deep, into the turbulent currents of intellectual thought surrounding the long history of scientific studies.

The editors and authors have intended only modest exploration—an audience appropriate glimpse—of the expanse of the philosophical waters. It would be inappropriate to force younger students to dive into the complexities of French narrative theory, evaluate the merits of ecofeminism, or suffer premature overexposure to elements of what can be an intellectually complex and acrimonious debate surrounding the tensions between science, philosophy, and cultural studies most often dubbed the "Science Wars." However, it is important for readers to know that vast oceans await. If this book allows students who are just beginning their studies of science and the history of science some insight into the diversity and rich complexity of the field, it will have achieved its primary objective.

Scientific Thought: In Context was designed to contain an extensive timeline as a chronological record of the evolution of science. The timeline serves as a valuable reference tool that allows readers to readily place events *in context* with scientific developments in other fields and historical milestones. Moreover, the timeline provides compelling reading in its own right. Starting with developments in ancient history, the timeline provides a narrative of the broad multicultural influences on the advancement of scientific thought.

To be sure, at its very best science transcends culture and unifies us. The deepest truths of science are knowable to all, regardless of age, gender, social condition, or cultural tradition.

Yet it is equally true that throughout the course of human history, science and society have advanced in a dynamic and mutual embrace, each influencing the other. While students learn of the grandeur and power of science and the scientific method, they should also know that scientific thought was (and is) often ignored in favor of cultural tradition, sifted through theological filters, or reduced to being a handmaiden to military tactics and weaponry. Scientific thought has been suppressed and swept from the philosophical stage during various periods in human history only to—by its virtue and strength as the most robust way to know the world—rekindle itself as a candle in the intellectual darkness.

It is important for all readers to understand that abundant evidence exists that sexism, racism, militarism, colonialism, and economic philosophy all influenced the course of human intellectual development, and the history of science is no exception. Studies of societal and cultural bias and prejudice also prove that selective picking and choosing of facts without scholarly discernment is, at best, unhelpful, and at worst—as in the case of Soviet Lysenkoism—deadly. Too readily does ignorance of science and scientific thought swell the ranks of book burning mobs, religious extremists, or cultish followers of pseudoscience.

With this in mind, the editors are indebted to a diversity of distinguished scholars for their generous contributions of time and compelling material. Given our intended audience, the selection and construction of entries was a balancing act of assessing what was interesting, informative, and intellectually understandable. Admittedly, the editors are scientists and not disposed to view science as a fashionable manifestation of political or popular culture. Accordingly, we do not agree with all of the philosophical and historical assertions made in this book. We have, however, encouraged scholars who represent highly diverse backgrounds and perspectives to express their views.

Ignorance, mysticism, and zealotry present true and grave dangers to science and the advancement of human rights and Enlightenment ideals. Within this context, the philosophical excesses on both sides of the "Science Wars" are trivial. Students not exposed to the intellectual heritage (and baggage) of scientific thought will be unable to make tempered and rational decisions regarding the appropriate application of scientific thought to modern issues.

Ideally, studies of the history of science from a cultural perspective can shed light upon previously overlooked contributors and their contributions and deepen appreciation for the commonality of science. Understanding the vulnerabilities of scientific thought, however historically transient, is also key to ensuring that science is advanced by intellectual ability and continues to offer humankind the best hope of a meritocracy of thought—where barriers of authority, class, wealth, religion, race or ethnicity might be cast aside.

K. Lee Lerner & Brenda Wilmoth Lerner, editors
Paris, France, December 2007

Primarily based in London and Paris, the Lerner & Lerner portfolio includes more than two dozen books and films that focus on science and science related issues.

The excerpt below comes from American physicist Richard Feynman's (1918–1988), *The Feynman Lectures on Physics.*

> The things with which we concern ourselves in science appear in myriad forms, and with a multitude of attributes. For example, if we stand on the shore and look at the sea, we see the water, the waves breaking, the foam, the sloshing motion of the water, the sound, the air, the winds and the clouds, the sun and the blue sky, and light; there is sand and there are rocks of various hardness and permanence, color, and texture. There are animals and seaweed, hunger and disease, and to the observer on the beach; there may be even happiness and thought. Any other spot in nature has a similar variety of things and influences. It is always as complicated as that, no matter where it is. Curiosity demands that we ask questions, that we try to put things together and try to understand this multitude of aspects as perhaps resulting from the action of a relatively small number of elemental things and forces acting in an infinite variety of combinations....
>
> A few hundred years ago, a method was devised to find partial answers to such questions. *Observation, reason*, and *experiment* make up what we call the *scientific method.*
>
> What do we really mean by "understanding" something? We can imagine that this complicated array of moving things which constitutes "the world" is something like a great chess game being played by the gods, and we are observers of the game. We do not know what the rules of the game are; all we are allowed to do is to *watch* the playing. Of course, if we watch long enough, we may eventually catch on to a few of the rules....
>
> —*Richard Feynman*

Editor's Note: Richard Feynman was awarded the 1965 Nobel Prize in Physics for his contributions to the advancement of quantum electrodynamics (QED). Dr. Feynman led an interesting life: As a young scientist he participated in the development of the first atomic bomb, and near the end of his life he was instrumental in determining the cause of the space shuttle *Challenger* disaster. Dr. Feynman played the bongo drums, loved diversity of culture, and expressed his views on the relationship of scientific thought to society through anecdotal stories contained in several books including *Surely You're Joking, Mr. Feynman.* He is considered by many to be one of the greatest teachers of physics.

About the *In Context* Series

Written by a global array of experts, yet aimed primarily at high school students and an interested general readership, the *In Context* series serves as an authoritative reference guide to essential concepts of science, the impacts of changes in scientific consensus, and the effects of science on social, political, and legal issues.

Cross-curricular in nature, *In Context* books align with, and support, national science standards and high school science curriculums across subjects in science and the humanities and facilitate science understanding important to higher achievement in the No Child Left Behind (NCLB) science testing. The inclusion of primary source documents and original essays written by leading experts serve the requirements of an increasing number of high school and international baccalaureate programs and are designed to provide additional insights on leading social issues, as well as spur critical thinking about the profound cultural connections of science.

In Context books also give special coverage to the impact of science on daily life, commerce, travel, and the future of industrialized and impoverished nations.

Each book in the series features entries with extensively developed words-to-know sections designed to facilitate understanding and increase both reading retention and the ability of students to understand reading in context without being overwhelmed by scientific terminology.

Entries are further designed to include standardized subheads that are specifically designed to present information related to the main focus of the book. Entries also include a listing of further resources (books, periodicals, Web sites, audio and visual media) and references to related entries.

In addition to maps, charts, tables and graphs, each *In Context* title has approximately 300 topic-related images that visually enrich the content. Each *In Context* title will also contain topic-specific timelines (a chronology of major events), a topic-specific glossary, a bibliography, and an index especially prepared to coordinate with the volume topic.

About This Book

The goal of *Scientific Thought: In Context* is to offer high-school and early college-age students insights into the essential facts and deeper cultural connections of scientific thought underpinning the study of modern science.

Because science increasingly plays a key role in shaping complex ethical and social debates, it is critical to have an understanding of the evolution of scientific thought. Arguably more critical than knowing the essential facts of science history (who discovered what and when) is the knowledge that advancements build upon earlier work and the realization that humanity for all our advances, has only recently grasped the most essential understanding of the nature and working of the cosmos.

In an attempt to enrich the reader's understanding of the mutually impacting relationship between science and culture, as space allows we have included primary sources that enhance the content of *In Context* entries. In keeping with the philosophy that much of the benefit from using primary sources derives from the reader's own process of inquiry, the contextual material introducing each primary source provides an unobtrusive introduction and springboard to critical thought.

General Structure

Scientific Thought: In Context is a collection of entries on diverse topics selected to provide insight into facets of scientific thought, especially touching on topics that relate to general science studies.

The articles in the book are meant to be understandable by anyone with a curiosity about science, and the first edition of *Scientific Thought: In Context* has been designed with ready reference in mind:

- Entries are arranged alphabetically, but key first words in each title help group subject areas such as physics or chemistry together for easier reference.
- The **chronology** (timeline) includes many of the most significant events in the history of science.
- An extensive **glossary** section provides readers with a ready reference for content-related terminology. In addition to defining terms within entries, specific "Words to Know" sidebars are placed within each entry.
- A **bibliography** section (citations of books, periodicals, Web sites, and audio and visual material) offers additional resources to those resources cited within each entry.
- A **comprehensive general index** guides the reader to topics and persons mentioned in the book.

Entry Structure

In Context entries are designed so that readers may navigate entries with ease. Toward that goal, entries are divided into easy-to-access sections:

- **Introduction**: A opening section designed to clearly identify the topic.
- **Words to Know** sidebar: Essential terms that enhance readability and critical understanding of entry content.
- Established but flexible **rubrics** customize content presentation and identify each section, enabling the reader to navigate entries with ease. Inside *Scientific Thought: In Context* entries readers will find a general scheme of organization. All entries contain a brief introduction, "Words to Know" sidebar, and then a section describing the essential history and scientific foundations of the topic. Sections titled "Impacts and Issues" or "Modern Cultural Connections" then interrelate key scientific, political, or social considerations related to the topic.
- More than 150 additional sidebars added by the editors enhance expert contributions by focusing on key areas, providing material for divergent studies or providing additional insights or context.
- If an entry contains a related primary source, it is appended to end of the author's text. Authors are not responsible for the selection or insertion of primary sources. Primary sources are designed to be related to the entry so as to stimulate critical thought, especially as to modern tangential connections to even the most ancient history of science.
- **Bibliography:** Citations of books, periodicals, Web sites, and audio and visual material used in preparation of the entry or that provide a stepping stone to further study.
- **"See also" references** clearly identify other content-related entries.

Scientific Thought: In Context Special Style Notes

Please note the following with regard to topics and entries included in *Scientific Thought: In Context*:

- Primary source selection and the composition of sidebars are not attributed to authors of signed entries to which the sidebars may be associated.
- Equations are, of course, often the most accurate and preferred language of science, and are essential to epidemiologists and medical statisticians. To better serve the intended audience of *Scientific Thought: In Context*, however, the editors attempted to minimize the inclusion of equations in favor of describing the elegance of thought or essential results such equations yield.
- A detailed understanding of biology and chemistry is neither assumed nor required for *Scientific Thought: In Context*. Accordingly, students and other readers should not be intimidated or deterred by the sometimes complex names of chemical molecules or biological classification. Where necessary, sufficient information regarding chemical structure or species classification is provided. If desired, more information can easily be obtained from any basic chemistry or biology reference.

Bibliography Citation Formats (How to cite articles and sources)

In Context titles adopt the following citation format:

Books

Feynman, Richard P. *The Feynman Lectures on Physics*. San Francisco, CA: Pearson/ Addison-Wesley, 2006.

Feynman, Richard P., and Davies, Paul (preface). Edited by Robert B. Leighton and Matthew Sands *Six Easy Pieces: Essentials of Physics Explained by Its Most Brilliant Teacher.* New York: Basic Books, 2005.

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Darwin, C.R., "Note on a Rock Seen on an Iceberg in 61° South Latitude." *Journal of the Geographical Society* 9 (March 1839): 528–529.

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Aristotle. *Physics.* The Internet Classics Archive. http://classics.mit.edu/Aristotle/physics.html (accessed August 28, 2007).

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National Biological Information Infrastructure. "Botany." http://www.nbii.gov/portal/community/Communities/Plants,_Animals_&_Other_Organisms/Botany/ (accessed February 16, 2008).

Alternative Citation Formats

There are, however, alternative citation formats that may be useful to readers and examples of how to cite articles in often used alternative formats are shown below.

APA Style

Books: Kübler-Ross, Elizabeth. (1969) *On Death and Dying.* New York: Macmillan. Excerpted in K. Lee Lerner and Brenda Wilmoth Lerner, eds. (2006) *Medicine, Health, and Bioethics: Essential Primary Sources*, Farmington Hills, Mich.: Thomson Gale.

Periodicals: Venter, J. Craig, et al. (2001, February 16). "The Sequence of the Human Genome." *Science*, vol. 291, no. 5507, pp. 1304–51. Excerpted in K. Lee Lerner and Brenda Wilmoth Lerner, eds. (2006) *Medicine, Health, and Bioethics: Essential Primary Sources*, Farmington Hills, Mich.: Thomson Gale.

Web Sites: Johns Hopkins Hospital and Health System. "Patient Rights and Responsibilities." Retrieved January 14, 2006 from http://www.hopkinsmedicine.org/patients/JHH/patient_rights.html. Excerpted in K. Lee Lerner and Brenda Wilmoth Lerner, eds. (2006) *Medicine, Health, and Bioethics: Essential Primary Sources*, Farmington Hills, Mich.: Thomson Gale.

Chicago Style

Books: Kübler-Ross, Elizabeth. *On Death and Dying.* New York: Macmillan, 1969. Excerpted in K. Lee Lerner and Brenda Wilmoth Lerner, eds. *Medicine, Health, and Bioethics: Essential Primary Sources*, Farmington Hills, MI: Thomson Gale, 2006.

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MLA Style

Books: Kübler-Ross, Elizabeth. *On Death and Dying*, New York: Macmillan, 1969. Excerpted in K. Lee Lerner and Brenda Wilmoth Lerner, eds. *Medicine, Health, and Bioethics: Essential Primary Sources*, Farmington Hills, Mich.: Thomson Gale, 2006.

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Web Sites: "Patient's Rights and Responsibilities." Johns Hopkins Hospital and Health System. January 14, 2006. <http://www.hopkinsmedicine.org/patients/JHH/patient_rights.html.> Excerpted in K. Lee Lerner and Brenda Wilmoth Lerner, eds. *Terrorism: Essential Primary Sources*, Farmington Hills, Mich.: Thomson Gale, 2006.

Turabian Style (Natural and Social Sciences)

Books: Kübler-Ross, Elizabeth. *On Death and Dying*, (New York: Macmillan, 1969). Excerpted in K. Lee Lerner and Brenda Wilmoth Lerner, eds. *Medicine, Health, and Bioethics: Essential Primary Sources*, (Farmington Hills, Mich.: Thomson Gale, 2006).

Periodicals: Venter, J. Craig, et al. "The Sequence of the Human Genome." *Science*, 291 (February 16, 2001): 5507, 1304–1351. Excerpted in K. Lee Lerner and Brenda Wilmoth Lerner, eds. *Medicine, Health, and Bioethics: Essential Primary Sources*, (Farmington Hills, Mich.: Thomson Gale, 2006).

Web Sites: Johns Hopkins Hospital and Health System. "Patient's Rights and Responsibilities." available from http://www.hopkinsmedicine.org/patients/JHH/patient_rights.html; accessed January 14, 2006. Excerpted in K. Lee Lerner and Brenda Wilmoth Lerner, eds. *Medicine, Health, and Bioethics: Essential Primary Sources*, (Farmington Hills, Mich.: Thomson Gale, 2006).

Using Primary Sources

The definition of what constitutes a primary source is often the subject of scholarly debate and interpretation. Although primary sources come from a wide spectrum of resources, they are united by the fact that they individually provide insight into the historical *milieu* (context and environment) during which they were produced. Primary sources include materials such as newspaper articles, press dispatches, autobiographies, essays, letters, diaries, speeches, song lyrics, posters, works of art—and, in the twenty-first century, web logs—that offer direct, first-hand insight or witness to events of their day.

Categories of primary sources include:

- Documents containing firsthand accounts of historic events by witnesses and participants. This category includes diary or journal entries, letters, e-mail, newspaper articles, interviews, memoirs, and testimony in legal proceedings.
- Documents or works representing the official views of both government leaders and leaders of other organizations. These include primary sources such as policy statements, speeches, interviews, press releases, government reports, and legislation.
- Works of art, including (but certainly not limited to) photographs, poems, and songs, including advertisements and reviews of those works that help establish an understanding of the cultural environment with regard to attitudes and perceptions of events.
- Secondary sources. In some cases, secondary sources or tertiary sources may be treated as primary sources. For example, if an entry written many years after an event, or to summarize an event, includes quotes, recollections, or retrospectives (accounts of the past) written by participants in the earlier event, the source can be considered a primary source.

Analysis of Primary Sources

The primary source material collected in this volume is not intended to provide a comprehensive or balanced overview of a topic or event. Rather, the primary sources are intended to generate interest and lay a foundation for further inquiry and study.

In order to properly analyze a primary source, readers should remain skeptical and develop probing questions about the source. Using historical documents requires that readers analyze them carefully and extract specific information. However, readers must also read "beyond the text" to garner larger clues about the social impact of the primary source.

In addition to providing information about their topics, primary sources may also supply a wealth of insight into their creator's viewpoint. For example, when reading a news article about an outbreak of disease, consider whether the reporter's words also

indicate something about his or her origin, bias (an irrational disposition in favor of someone or something), prejudices (an irrational disposition against someone or something), or intended audience.

Students should remember that primary sources often contain information later proven to be false, or contain viewpoints and terms unacceptable to future generations. It is important to view the primary source within the historical and social context existing at its creation. If, for example, a newspaper article is written within hours or days of an event, later developments may reveal some assertions in the original article as false or misleading.

Test New Conclusions and Ideas

Whatever opinion or working hypothesis the reader forms, it is critical that they then test that hypothesis against other facts and sources related to the incident. For example, it might be wrong to conclude that factual mistakes are deliberate unless evidence can be produced of a pattern and practice of such mistakes with an intent to promote a false idea.

The difference between sound reasoning and pseudoscientific beliefs, preposterous conspiracy theories, or the birth of urban legends lies in the willingness to test new ideas against other sources rather than rest on one piece of evidence, such as a single primary source, that may contain errors. Sound reasoning requires that arguments and assertions guard against argument fallacies that utilize the following:

- false dilemmas (only two choices are given when in fact there are three or more options);
- arguments from ignorance (*argumentum ad ignorantiam*; because something is not known to be true, it is assumed to be false);
- possibilist fallacies (arguments in which "it could be" is usually followed by an unearned "therefore, it is." This is a favorite among conspiracy theorists, who attempt to demonstrate that a factual statement is true or false by establishing the possibility of its truth or falsity.);
- slippery slope arguments or fallacies (a series of increasingly dramatic consequences is drawn from an initial fact or idea);
- begging the question (the truth of the conclusion is assumed by the premises);
- straw man arguments (the arguer mischaracterizes an argument or theory and then attacks the merits of their own false representations);
- appeals to pity or force (the argument attempts to persuade people to agree by sympathy or force);
- prejudicial language (values or moral goodness, good and bad, are attached to certain arguments or facts);
- personal attacks (*ad hominem*; an attack on a person's character or circumstances);
- anecdotal or testimonial evidence (stories that are unsupported by impartial observation or data that is not reproducible);
- *post hoc* (after the fact) fallacies (because one thing follows another, it is held to cause the other);
- the fallacy of the appeal to authority (the argument rests upon the credentials of a person, not the evidence).

Despite the fact that some primary sources can contain false information or lead readers to false conclusions based on the "facts" presented, they remain an invaluable resource regarding past events. Primary sources allow readers and researchers to come as close as possible to understanding the perceptions and context of events and thus to more fully appreciate how and why misconceptions occur.

Glossary

A

ABERRANT: Deviation from some specified standard. In optics, the failure of a lens or mirror to focus an image perfectly at its intended focal point. In astronomy, the apparent displacement of an observed object due to the relative motion of the object and the telescope.

ABIOTIC: The portion of an ecosystem that is not living, such as water or soil.

ABSOLUTE MAGNITUDE: The apparent brightness of a star, measured in units of magnitudes, at a fixed distance of 10 parsecs.

ABSORPTION SPECTRUM: The spectrum formed when light passes through a cool gas.

ACADEMY: The world of university researchers, teachers, and students is often referred to as the academy. Specific academies, such as the U.S. National Academy of Sciences, are groups of experts asked to serve as a scientific advisory body, usually to a government.

ACCRATIELEON: A change in the velocity (either magnitude or direction) of an object.

ACCRETION DISK: When gas and dust are attracted to a heavy, spinning object such as a neutron star or black hole, they form a disk that rotates at right angles to the spin axis of the heavy object. Material from the innermost edge of the accretion disk continually falls into the heavy object.

ACETYLCHOLINE: One of many neurotransmitters employed by the human body and used throughout the nervous system. A neurotransmitter is a chemical released by nerve cells into a synapse—the narrow, fluid-filled space separating it from another nerve cell—in order to stimulate chemical activity in that other cell.

ACHROMATIC LENS: Achromatic lenses are built by forming lenses out of sandwiched parts that are made of different types of glass. The optical properties of each part of the lens compensate for or balance the properties of the others, reducing aberrations caused by other types of lenses. For example, simple glass lenses have the unwanted property of acting as prisms, that is, dividing white light up into rainbow-like spectra: This effect is termed chromatic aberration. Uncorrected lenses also suffer from spherical aberration, which is the focusing of different colors at different distances from the lens rather than at a single image plane.

ACQUIRED CHARACTERISTICS: Characteristics that are acquired by a plant or animal by interacting with its environment. These may include scars, lost limbs, calluses, strengthened or weakened muscles, and so forth. Although some acquired characteristics (e.g., low body weight due to malnutrition) can be inherited briefly and in part, it is now known that inheritance of acquired characteristics is not a significant factor in biological evolution.

ACUPUNCTURE: The Chinese practice of treating disease or pain by inserting very thin needles into specific sites in the body.

ADAPTIVE RADIATION: In evolutionary biology, adaptive radiation occurs when a species colonizes a new environment and rapidly evolves a wide range of new forms to adapt to niches or opportunities in that environment. Here "radiation" refers to the radiating

or fanning-out of the species into ecological opportunities, not to nuclear radiation. A classic example of adaptive radiation is the history of cichlid fishes in the Great Rift Lakes of Africa. In Lake Victoria, for example, over 500 species of cichlid fish have evolved from a single ancestral species in the last 12,000 years or less.

ADDISON'S DISEASE: A disorder resulting from insufficient secretion of hormones from the adrenal cortex, named after the doctor who first characterized it, Englishman Thomas Addison (1793–1860). Its symptoms include weakness and bronze discoloration of the skin.

ADJUVANT THERAPY: Cancer treatments (radiation, chemotherapy) that are given after surgery in order to prevent recurrence of a tumor.

ADRENAL GLANDS: A pair of endocrine glands that sits atop the kidneys and releases hormones directly into the bloodstream. The adrenals are flattened, somewhat triangular bodies that, like other endocrine glands, receive a rich blood supply. The phrenic (from the diaphragm) and renal (from the kidney) arteries send many small branches to the adrenals, while a single large adrenal vein drains blood from the gland.

ADULT STEM CELL: A renewable and unspecialized cell found among specialized cells in a tissue or organ.

ALBEDO EFFECT: Albedo is the ability of a planet, moon, or other body in space to reflect light. Brighter objects have higher albedo, darker objects lower albedo. In climate science, the albedo effect is the influence of Earth's albedo on climate. Bright features such as ice caps tend to reflect solar energy into space, cooling the climate. Melting ice lowers Earth's albedo, making it a more efficient absorber of solar energy and tending to warm its climate.

ALCHEMY: The study of the reactions of chemicals in pre-modern times. It was often, but not always, directed by the goal of making gold. In a general sense, alchemy is perceived as the transmutation (transformation) of a common substance to something rare and valuable. Medieval alchemists are often portrayed as little more than quacks attempting to make gold from lead. This depiction is not entirely correct. To be sure, there were such characters, but for real alchemists, called adepts, the field was an almost divine mixture of science, mystery, and philosophy.

ALCOHOL: Any of the large number of molecules containing a hydroxyl (–OH) group bonded to a carbon atom to which only other carbon atoms or hydrogen atoms are bonded.

ALGORITHM: A mathematical relation between an observed quantity and a variable used in a step-by-step mathematical process to calculate a quantity.

ALLELE: Any of two or more alternative forms of a gene that occupy the same location on a chromosome.

ALLOGRAFT: Transplanted tissues or organs from donors of the same species.

ALLOTRANSPLANTATION: The transplantation of an organ to an individual from an animal of the same species, e.g., human to human. This is the most common form of transplantation. Xenotransplantation, on the other hand, is the transplantation of an organ from an animal of another species, e.g., a pig's heart valve into a human.

ALPHA PARTICLE: A positively charged nuclear particle that consists of two protons and two electrons; it is ejected at a high speed from disintegrating radioactive materials.

AMINO ACID: One of about two dozen relatively simple chemical compounds from which proteins are made, amino acids are the building blocks of proteins and serve many other functions in living organisms. They are nitrogen-containing organic compounds that consist of at least one acidic carboxyl group (COOH) and one amino group (NH_2). In alpha amino acids that are contained in the proteins found in cells, these two groups are both attached to a carbon atom, which also carries a hydrogen atom, plus a side chain known as the R group. The R group varies from one amino acid to another and gives each amino acid its distinctive properties. The prime function of DNA (deoxyribonucleic acid) is to carry the information needed to direct the proper sequential insertion of amino acids into protein chains during protein synthesis (translation). Although relatively simple compounds, amino acids can vary widely; to date, more than 80 different amino acids have been found in living organisms. Of these 80 amino acids, 22 are considered the precursors of animal proteins.

AMORPHOUS: A substance that lacks any well-defined structure. In earth science, substances made of randomly-organized atoms, such as glass. Crystals, whose atoms are organized in a definite pattern, are not amorphous; therefore, amorphous substances are sometimes said to be acrystalline (i.e., not-crystalline).

AMPLIFICATION: Increasing the strength of some signal such as the amount of electrical current passing through a transistor.

AMPUTATION: The surgical or accidental removal of a limb (arm or leg) or a distinct part of a limb (finger, toe, hand, foot, etc).

ANABOLISM: The process by which energy is used to build up complex molecules.

ANADROMOUS: Fish that migrate up streams and rivers to mate and produce offspring are said to be anadromous (from the Greek for "up-running"); all other fish are catadromous.

ANAEROBIC: Living or growing in an atmosphere lacking oxygen.

ANALOG: A process that is fluctuating or continually changing. In electronics, an analog signal is a base alternating current frequency that is modified, usually by amplification or varying of the frequency, in order to add information to the signal. Conventional forms of television and telephone transmissions use analog technology.

ANALOGOUS STRUCTURE: In evolutionary biology, an analogous structure is a part of a creature's anatomy that resembles a part of some other creature's anatomy, even though the two creatures are not related by evolutionary descent. The two structures evolved independently to perform the same function; for example, the eye of the squid and the human eye are analogous structures, as are birds' wings and bats' wings. Structures that resemble each other because of descent from a shared ancestor are homologous, not analogous.

ANALYSIS: In chemistry, the process of separating out the constituents of a complex chemical substance.

ANAPHYLAXIS: Any severe allergic reaction to a substance to which the body has been previously exposed. In the most severe form, the patient experiences anaphylactic shock, which may cause death through stopped breathing. Insect stings and penicillin are two common triggers for anaphylactic shock.

ANASTOMOSE: To make a connection between tubes in the body (blood vessels, digestive organs, or the like) that joins the mid-part of one tube to another, as opposed to connecting them end-to-end. Anastomosis may occur surgically or in the natural growth of a network of vessels. For example, the capillary beds that deliver blood to most of the body's tissues form an extensively anastomosed network.

ANEURYSM: A bulging or ballooning of part of a blood vessel. Aneurysms can burst, causing internal bleeding and severe damage, depending on the location or size of the break: a cerebral aneurysm can destroy part of the brain or cause death, while an aortic aneurysm is usually immediately fatal.

ANGULAR SIZE: The size of an object in the sky, measured in degrees.

ANIMALCULE: The term "animalcules," from Latin, means "tiny animals." The inventor of the microscope, Dutch scientist Anton van Leeuwenhoek (1632–1723), was the first person to observe microscopic animals and used this term to describe them. The word had previously been applied occasionally to any small animals, such as mice or insects.

ANTHROPOCENTRISM: The tendency to view human beings and their needs, values, and desires as all-important or central to the cosmos (from the Greek for "human-centered"). For example, the belief that Earth rotates on its axis so that humans can have a daily rest period would be anthropocentric.

ANTHROPOGENIC: Made by people or resulting from human activities. Usually used in the context of emissions that are produced as a result of human activities.

ANTIBIOTIC: Natural or synthetic compounds that kill or reduce populations of bacteria. There are a myriad of different antibiotics that act on different structural or biochemical components of bacteria. Antibiotics have no direct effect on viruses. Also, a specific drug, such as penicillin, that is used to fight infections caused by bacteria.

ANTIBODIES: Large, Y-shaped proteins found in blood that lock on to specific substances foreign to the body (antigens). Typical antigens are molecules found on the surfaces of viruses and bacteria. Some antibodies, when bound to antigens, act as flags targeting the antigen for attack by white blood cells; others combine with other blood molecules to attack the antigen directly. If a person's blood already contains antibodies for a particular antigen, the person's immune system attacks that antigen as soon as it appears. This is the basis of acquired immunity to specific viruses and bacteria, whether natural or instilled by immunization.

ANTIBODY: An antibody, or Y-shaped immunoglobulin, is a protein molecule found in the blood that is created by the immune system in response to the presence of an antigen (a foreign substance or particle). It marks foreign microorganisms in the body for destruction by other immune cells. There are a myriad of different antigens that are presented

to the immune system. Hence, there are a myriad of antibodies that can be formed.

ANTIGEN: Any substance that the body considers foreign, such as a bacterial cell, that stimulates the body's immune system to produce antibodies. Antibodies, or Y-shaped immunoglobulins, are proteins that inactivate the antigen and help to remove it from the body. While antigens can be the source of infections from pathogenic (disease-causing) bacteria and viruses, organic molecules detrimental to the body from internal or environmental sources also act as antigens. Antigens are usually proteins or polysaccharides.

ANTIOXIDANTS: Antioxidants are substances, often found in foods and capable of being transferred to body cells, that interfere with oxidation reactions. These are reactions involving free radicals (free-floating charged molecules). Free radicals can damage cell chemistry by triggering unwanted chemical reactions; antioxidants reduce this damage.

ANTIPARTICLE: In particle physics, most fundamental particles having non-zero rest mass (e.g., neutron, proton, electron) have an antiparticle that is an almost perfect mirror-image of the particle. When a particle and its antiparticle meet, they annihilate each other, releasing all their energy in the form of photons. At the big bang, about 13.7 billion years ago, slightly more particles were produced than antiparticles. After all particle-antiparticle pairs annihilated each other, the remaining fraction of particles became all the ordinary matter seen in the universe today.

ANTISEPTIC: A substance that prevents or stops the growth and multiplication of pathogenic (disease-causing) microorganisms in or on living tissue. An antiseptic may kill a microorganism, but it does not necessarily have to. The treated microbes may only be weakened. The weaker, slower-growing microbes may then be more susceptible to the defense mechanisms of the host.

ANTISERUM (PLURAL: ANTISERUMS OR ANTISERA): A clear liquid blood fraction that contains certain antibodies against a specific agent, usually a bacterium or bacterial toxin, that is used to treat persons infected with that agent. Both antisera and antitoxins are means of proactively combating infections. The introduction of compounds to which the immune system responds is an attempt to build up protection against microorganisms or their toxins before the microbes actually invade the body. An antiserum is injected into the body to confer immunity against a pathogen (disease-causing organism) that is targeted by the antibody contained in the antiserum.

ANTITOXIN: An antidote to a toxin that neutralizes its poisonous effects. Both antisera and antitoxins are means of proactively combating infections. The introduction of compounds to which the immune system responds is an attempt to build up protection against microorganisms or their toxins before the microbes actually invade the body.

AORTA: The main artery of the body that arises from the left ventricle of the heart and runs down the body in front of the spine, supplying blood through branch arteries throughout the body.

APERIODICITY: A pattern or process that is not periodic; that is, it does not repeat itself after a fixed time interval or distance. Aperiodic geometric patterns or tilings were proposed in the 1960s and have since been found to be of importance in crystallography and the physics of solids.

APPARENT (OR RELATIVE) MAGNITUDE: The apparent brightness of a star as seen from Earth.

APPLIED GEOGRAPHY: Geographic knowledge applied to human activities such as settlement planning, agriculture, environmental protection, resource extraction, disaster relief, or military operations.

APPLIED MATHEMATICS: All mathematical knowledge used in physical science, economics, social science, and technology. Applied mathematics is often contrasted to pure mathematics, which is pursued without regard to any specific real-world use.

APPLIED SCIENTIFIC FIELD: An area of scientific knowledge that is used for some practical purpose—amusement, war, medicine, transport, communication, or other. Physics, chemistry, mathematics, biology, and other fields all have applied areas. Labeling some knowledge "applied" does not imply that knowledge that is not applied directly is useless: first, it satisfies the human desire to know, and second, the applied knowledge in each field would not exist or make sense without all the knowledge of the field, including that which is not directly applied.

APPRENTICE: A person serving at low wages in order to learn a skill, trade, or craft from an established practitioner. Apprenticeship was widespread in the European economy during the late Middle Ages.

ARCHAEOASTRONOMER: A scientist who studies the astronomical practices of ancient peoples, especially as reflected in the monuments and religious structures built by those peoples. For example, an archaeoastronomer might analyze the Great Pyramids or the megaliths of Stonehenge to discern their

astronomical properties and the importance of those properties for their builders.

ARCHAEOASTRONOMY: The study of the astronomical practices of ancient peoples, especially as reflected in the monuments and religious structures built by those peoples.

ARCHETYPE: In the theories of Swiss psychologist Carl Jung (1875–1961), an image or event that is innately possessed by the minds of all human beings and that therefore recurs in stories and dreams as a basic, meaningful pattern across history and cultures. Examples of Jungian archetypes are birth and death, mother and father, the trickster and the wise woman, the bride and the hero.

AROMATIC: In organic chemistry, a compound whose molecular structure includes some variation of the benzene ring.

ARPANET: Early Department of Defense program, initiated by the Defense Advanced Research Projects Agency (DARPA), that led to the development of the Internet.

ARTERY: Any of the large elastic-walled blood vessels that carry blood away from the heart to other parts of the body.

ARTHAŚĀTRA: A prose work describing the principles of statecraft or political economy—how to run a country—that was written in India some time in the first few centuries AD. It is often compared to *The Prince* by Italian diplomat Niccolò Machiavelli (1469–1527), which also recommends ruthless measures for stabilizing centralized political power.

ASTROLABE: An instrument used throughout the Middle East and Europe from classical times through the Renaissance as an aid in observing star positions and calculating longitude and local time. It was used in astronomy, astrology, and navigation, and was a precursor of the slide rule. Astrolabes varied in design; typically, one consisted of a metal disk marked with lines conveying astronomical information and a center-mounted rotating pointer.

ASTROLOGY: The practice of studying the apparent motions of the planets, moon, sun, and stars in order to draw conclusions about human character (supposedly affected by sky patterns at the time of one's birth) or about the future of a person's affairs. Astrology has been practiced since at least about 3000 BC; European, Indian, and Chinese astrological systems have all been developed. Although astrology is still widely popular, it is not a form of science.

ASTRONOMICAL UNIT (AU): A unit of measurement equal to the average distance from Earth to the sun: 93 million miles (150 million km). Distances within the solar system are frequently expressed in AUs.

ASTRONOMY: The study of the physical and chemical properties of objects and matter outside Earth's atmosphere.

ATOM: The smallest particle in which an element can exist.

ATOMIC CLOCK: A device for keeping time based on natural oscillations within atoms.

ATOMIC NUMBER: The number of protons in the nucleus of an atom; the number that appears over the element symbol in the periodic table.

ATOMIC WEIGHT: A quantity indicating atomic mass that tells how much matter there is in something or how dense it is, rather than its weight. Atomic weight is expressed in units known as atomic mass units (amu).

ATTENUATED: A bacterium or virus that has been weakened, often used as the basis of a vaccine against the specific disease caused by the bacterium or virus.

AUGURS: Priests in ancient Rome who believed that they could discern the will of the gods by interpreting the flight patterns of birds.

AURICLE: Also known as pinna or external ear; the flap-like organ on either side of the head. Also, an atrium of a heart.

AUSPICES: In pre-Christian Roman religion, auspices were patterns of bird flight observed by priests called augurs and interpreted as revealing the will of the gods.

AUTAPOMORPHY: In evolutionary biology, an autapomorphy is a feature of a clade (a species or group of species evolved from a common ancestor) that is unique and original to that clade, that is, which was not inherited from earlier species. For example, hair is an autapomorphy of the clade of mammals; articulate speech is an autapomorphy of human beings.

AUTOGRAFT: A type of skin graft that uses tissue from another part of the patient's own body, and therefore has cells with the same genes, reducing the chances of complications associated with tissue rejection.

AUTOIMMUNE DISEASE: A disease in which the body's defense system attacks its own tissues and

organs. Autoimmune diseases are conditions in which a person's immune system attacks the body's own cells, causing tissue destruction. Autoimmune diseases are classified as either general, in which the autoimmune reaction takes place simultaneously in a number of tissues, or organ specific, in which the autoimmune reaction targets a single organ. Autoimmunity is accepted as the cause of a wide range of disorders, and it is suspected to be responsible for many more. Among the most common diseases attributed to autoimmune disorders are rheumatoid arthritis, systemic lupus erythematosis (lupus), multiple sclerosis, myasthenia gravis, pernicious anemia, and scleroderma.

AUTOPSY: An examination, usually by dissection, of a body after death to determine the cause of death, extent of injuries, or other factors.

AXIOM: A mathematical statement accepted as true without being proven.

AZOIC THEORY: In the mid-nineteenth century, British naturalist Edward Forbes (1815–1854) proposed that the sea bottom was lifeless (azoic) at depths greater than 18,000 feet (5.5 km); he was mistaken. In geology, azoic rocks are those dating to the period before life existed on Earth.

B

B CELLS: Blood cells found in the vertebrate immune system that are responsible for making antibodies. There are several types of B cell, all with different roles in antibody production.

BACTERIA: Single-celled microorganisms that live in soil, water, plants, and animals. Their activities range from the development of disease to fermentation. They play a key role in the decay of organic matter and the cycling of nutrients. Some bacteria are agents of disease. Bacteria range in shape from spherical to rod-shaped to spiral. Different types of bacteria cause many sexually transmitted diseases, including syphilis, gonorrhea, and chlamydia. Bacteria also cause diseases ranging from typhoid to dysentery to tetanus. Bacterium is the singular form of bacteria.

BACTERIOLYTIC: Killing bacteria, usually by dissolving the cell membrane.

BACTERIOPHAGE: A bacteriophage, or phage, is a virus that infects a bacterial cell, taking over the host cell's genetic material, reproducing itself, and eventually destroying the bacterium. The word phage comes from the Greek word *phagein*, meaning "to eat." A particular bacteriophage specifically infects one or a limited number of bacterial species.

BACTERIUM (PLURAL: BACTERIA): Any single-celled, microscopic, prokaryotic (nucleus-lacking) animal. Going by either total mass or species count, bacteria are Earth's dominant form of life.

BALMER SERIES: A hydrogen atom, if excited by added energy, releases photons with a variety of particular energies. When displayed as a spectrum, these particular energies show up as spikes or lines, which have been categorized into six groups or series. In 1885, Swiss mathematician Johann Balmer (1825–1898) produced a mathematical formula that predicted the locations of the lines in one particular group; this series was named the Balmer series in his honor.

BAND SPECTRUM: A representation of the mixture of different frequencies of light (or other vibrations) from a given source. All substances are made of atoms, and light is emitted from atoms when their electrons are excited (raised to higher energy levels) by receiving energy. When excited electrons lapse to lower energy levels, they emit light at particular frequencies, giving rise to spectral lines. In some substances, especially molecules, these lines can be so closely spaced as to appear like a continuous band rather than a series of spectral spikes. These spectra are termed band spectra.

BAND THEORY: In quantum physics, the physical theory that describes what bands are available in a substance and how electrons will occupy those bands. A band is a specific energy level that an electron may possess in a given atom or molecule. Band values vary from substance to substance and are often numerous.

BAROMETER: An instrument used to measure atmospheric pressure. A standard mercury barometer has a glass column about 30 inches (72.6 cm) long, closed at one end, with a mercury-filled reservoir. Mercury in the tube adjusts until the weight of the mercury column balances the atmospheric force exerted on the reservoir. High atmospheric pressure forces the mercury higher in the column. Low pressure allows the mercury to drop to a lower level in the column. An aneroid barometer uses a small, flexible metal box called an aneroid cell. The box is tightly sealed after some of the air is removed, so that small changes in external air pressure cause the cell to expand or contract.

BARYON: Subatomic particles that participate in strong force interactions. Baryons are composed of three quarks (or three antiquarks). Protons and neutrons are among the baryons.

BASE PAIR: In DNA molecules, the nitrogenous bases bind together in very restricted and specific ways to form base pairs between DNA strands. In DNA, adenine always bonds with thymine (A-T bond) on the opposite strand and cytosine always bonds with guanine to form a (C-G) base pair between strands of the DNA helix.

BASE PAIRS: In the long, twisted-ladder-shaped molecules used by all living things for passing on information to offspring—DNA and RNA—a base pair corresponds to a single rung in the ladder. Each half of each rung is a cluster of atoms called a base, so each rung is a pair of bases, a base pair. There are four bases in DNA, namely adenine, guanine, cytosine, and thymine. Adenine always bonds with thymine, and guanine with cytosine. The series of base pairs in a DNA molecule specifies a gene. Often a gene acts as a recipe for building a protein or may control the way other genes are used.

BEHAVIORALISM: The school of thought in political science that seeks to describe human group behavior mathematically.

BENTHOS: The plants and animals dwelling at the bottom of a body of water.

BENZENE: A ring-shaped hydrocarbon molecule that has long been used as an industrial solvent, that is, a liquid in which other substances can be dissolved. However, benzene is now known to be a potent cause of cancer and is not widely used.

BERNOULLI'S LAW: Named after Swiss mathematician David Bernoulli (1700–1782), a mathematical description of the fact that any increase in the velocity of a moving liquid decreases the pressure of that liquid.

BESTIARY: In medieval Europe, books devoted to describing a variety of animals. These precursors of later works in scientific natural history often drew moral lessons from the supposed behaviors of animals, such as the foresight exercised by groups of sleeping cranes in always posting a sentry.

BETA DECAY: Process by which a neutron in an atomic nucleus breaks apart into a proton and an electron.

BETA PARTICLE: An electron emitted by an atomic nucleus.

BIFURCATION: Splitting in two, especially of a physical structure such as a limb or blood vessel. The letter Y, for example, shows a bifurcation halfway up the stem.

BIG BANG: The beginning of the universe's expansion from a state of infinite or near infinite density and temperature to its present cool, dispersed state. It occurred about 13.7 billion years ago. It was not an explosion in empty space, like a bomb going off in a void, but is better characterized as an explosion of space itself.

BINARY: The binary number system uses only two digits, 0 and 1, and is basic to computer science. In astronomy, a binary star is a pair of stars orbiting each other and is sometimes called "a binary."

BINOMIAL NOMENCLATURE: System of naming plants and animals in which each species is given a two-part name, the first being the genus and the second being the species.

BIOCHEMICAL: A term used to define the chemical activity in living organisms.

BIODIVERSITY: Literally, "life diversity"; the number of different kinds of living things. The wide range of organisms—plants and animals—that exist within any given geographical region.

BIOENGINEERING: The term bioengineering is often used to denote the creation of artificial organs, organ parts, or tissue replacements that can be installed in the body to repair disease or injury. For example, the installation of a mitral heart valve is bioengineering.

BIOGEOGRAPHY: The study of the distribution and dispersal of plants and animals throughout the world.

BIOME: Well-defined terrestrial environment (e.g., desert, tundra, or tropical forest). The complex of living organisms found in an ecological region.

BIOMETRIC: The statistical analysis of biological data. In technology, biometric systems measure the distinctive properties of individual creatures, especially people, in order to identify them uniquely. Fingerprinting, retina or iris scanning, and computerized face recognition are biometric technologies.

BIOPIRACY: The exploitation of knowledge about biological systems—crop varieties, herbal medicines, or the like—originally created by an indigenous people. Biopirates profit from traditional biological know-how without compensating its creators.

BIOREMEDIATION: The use of living organisms to help repair damage such as that caused by oil spills.

BIOTECHNOLOGY: Any technique that uses parts of living organisms to create or modify products, plants, animals, or microorganisms for specific uses.

BIOTIC: Biotic refers to living organisms; for example, a material obtained from living organisms is a biotic material.

BIOTIC RESISTANCE HYPOTHESIS: The view that a native biota (system of plants and animals) inhabiting a region resists invasion by foreign species because the invaders are hindered by strong interactions with native species, including natural enemies (e.g., native plant-eaters). This theory is often contrasted to the natural-enemies hypothesis, which states that invasive species spread more readily because they do not encounter natural enemies.

BLACK BILE: The ancient Greek and Roman theory of medicine stated that four basic substances, the humors, exist in the human body, and that disease or exaggerated personality is caused by an imbalance among the humors. The four humors were blood, phlegm, yellow bile, and black bile; an excess of black bile was believed to cause melancholy and depression.

BLACK HOLE: A single point of infinitely small space containing the mass and gravity of a collapsed massive star. The gravity is so strong that light cannot escape.

BLACKBODY: An ideal emitter that radiates energy at the maximum possible rate per unit area at each wavelength for any given temperature. A blackbody also absorbs all the radiant energy incident on it; i.e., no energy is reflected or transmitted.

BLOODLETTING: Bloodletting, also known as phlebotomy, is the deliberate medical release of blood from the body, whether by allowing leeches to feed on the patient or by cutting a blood vessel. This technique was practiced by doctors from Greco-Roman times to the nineteenth century but was rarely of benefit and often harmful. However, there are certain rare medical conditions, such as hemochromatosis, in which the patient has excessive red blood cells and must undergo regular therapeutic bloodletting.

BOHR MODEL: Neils Bohr (1885–1962), a Danish physicist, proposed the Bohr model of the atom in 1913, at a time when physicists were still struggling to understand atomic structure. In the Bohr model of the atom, negatively charged electrons are bound to a positively charged (and much more massive) nucleus by electrostatic attraction, but prevented from falling into the nucleus by the fact that they can only exist in certain permitted energy states as described by quantum mechanics.

BOOLEAN ALGEBRA: A system that applies algebra to logic. Also called symbolic logic, it converts logic into mathematical symbols.

BOSON: According to the modern Standard Model of particle physics, all particles are either bosons or fermions. All forces are explained as exchanges of virtual bosons between fermions. Bosons have integer spin values; photons are bosons (spin = 1). The only particle predicted by the Standard Model that had not been experimentally observed as of early 2008 was the Higgs boson.

BOTANY: The branch of biology involving the study of plant life.

BOUNDED RATIONALITY: Economist and scientist Herbert Simon (1916–2001) won a Nobel Prize in Economics for his theory of bounded rationality, which challenged economists' traditional assumption that consumers and producers always make perfectly rational choices to maximize utility and profits. Instead, Simon said, they make choices whose rationality is limited by access to computational resources—that is, by lack of information about alternatives, time in which to ponder them, or education that would enable them to grasp a situation's complexities, for example.

BOVINE SPONGIFORM ENCEPHALOPATHY: A brain disease in cows caused by malformed proteins. Bovine means cow; spongiform refers to the spongy texture of the brains of cows that have the disease in advanced form; and encephalopathy means brain-disease. Eating tissue, especially nerve tissue, from cows infected by prions causes variant Creutzfeldt-Jakob disease in humans. Both bovine spongiform encephalopathy and Creutzfeldt-Jakob disease cause mental breakdown and eventual death.

BREWING: The practice of encouraging the growth of yeast—microscopic fungi—in mixtures of water and plant material to turn plant sugars into ethyl alcohol and carbon dioxide. After filtering and aging, the resulting mixture becomes an alcoholic beverage. If carbon dioxide is retained, it becomes bubbles, as in beer and champagne; if it is allowed to escape, non-carbonated alcoholic beverages such as wine are created.

C

C: In physics, for over a century, the italicized Roman letter c, sometimes written c_0, has stood for the speed of light in a vacuum, namely 670,616,629 miles

per hour (1,079,252,848 km/h) or, as more commonly expressed in science, 2.99×10^7 m/s. This speed is constant, that is, no matter how fast a source and observer are moving with respect to each other, the observer will always measure the speed of light as *c*. In media such as air or glass, light travels more slowly, but still has the property of being constant for all observers.

CABBALISTIC: The Cabbalah (or Kabbalah) is an ancient Jewish tradition of biblical interpretation, still practiced by some Hasidic Jews. Any symbol or phrase having, or supposed to have, a secret, mystical sense is often described as cabbalistic.

CALCINATION: An old term used to describe the process of heating metals and other materials in air.

CALCULUS: The branch of mathematics that uses algebra to calculate changing quantities and motion.

CALORIC THEORY OF HEAT: In the 1780s, French scientist Antoine Lavoisier (1743–1794) proposed that heat is a substance resembling a fluid that can flow from one object to another. This fluid he named caloric. In the mid-1800s and beyond, this theory was replaced by the modern understanding of heat, which is that heat is the motion of large numbers of particles in a substance (atoms or molecules).

CALX: The powdery residue, generally of metal (metallic oxide), formed from the ore and oxygen from the air when a metal-bearing rock or mineral is heated to high temperature.

CAMBRIAN EXPLOSION: Relatively sudden evolution of a wide variety of multicellular forms of life at the beginning of the Cambrian period, about 530 million years ago, after billions of years during which Earth was inhabited almost entirely by single-celled organisms. A few forms of multicellular life did appear shortly before the Cambrian Explosion. The explosion may have been triggered by the ending of a major snowball Earth period or by the achievement of sufficiently high oxygen levels thanks to billions of years of oxygen production by algae (single-celled aquatic plants).

CAMERA OBSCURA: A dark room or box with a light-admitting hole that projects an image of the scene outside.

CAPACITY: In physics and electronics, capacity is a synonym for capacitance, the ability of a device to store electric charge.

CARAPACE: A protective covering or shield on an animal's back, e.g., the upper part of a turtle's shell.

CARBOHYDRATE: An organic compound present in the cells of all living organisms and a major organic nutrient for human beings; consists of carbon, hydrogen, and oxygen, and makes up sugar, starch, and cellulose.

CARCINOGENIC: The property of causing cancer. Common carcinogenic chemicals are asbestos, tobacco smoke, and benzene. Some viruses can also be carcinogenic.

CARD CATALOG: A device used for storing and retrieving information about the contents of a library. Each item in the library's collection—book, audio recording, or other—was identified on a small paperboard card. These cards were ordered alphabetically and stored in small drawers that could be browsed by a user looking for a particular item. The card recorded the physical location of the item, which the user then went and obtained. Since the 1980s, computer terminals have almost completely replaced card catalogs.

CARNOT CYCLE: A Carnot cycle—named after the French scientist who first identified such a cycle, Nicolas Carnot (1796–1832)—is a series of temperature-and-pressure states through which a system can be changed, returning eventually to its starting state. In moving through a Carnot cycle, a system does work on its environment, such as turning a shaft or moving a piston. All engines that turn heat into useful mechanical work are based on thermodynamic cycles like the Carnot cycle, but the Carnot cycle is the most efficient possible cycle and can only be approximated in a real machine.

CARTOGRAPHY: The science of mapmaking

CATABOLISM: The process by which large molecules are broken down into smaller ones with the release of energy.

CATALYST: Substance that speeds up a chemical process without actually changing the products of reaction.

CATASTROPHISM: School of thought in geology that holds that the rates of processes shaping Earth have varied greatly in the past, occasionally acting with violent suddenness (catastrophes). In nineteenth-century geology, two main approaches to explaining how Earth achieved its present geographic state, including its fossil record, seas, mountains, valleys, and the like, were debated by scientists. Some favored

gradualism, the theory that slowly operating causes still visible in the environment, such as erosion, were completely responsible for Earth's geological history. Others favored catastrophism, the theory that sudden events (catastrophes) had caused geological upheavals and mass extinctions in the past. Modern science admits the reality of both gradual and catastrophic causes.

CATHARTIC: Emotional relief through the expression or experience of strong emotions has, since the early 1600s, been termed cathartic (from the Greek *katharsis*, for "cleansing"). The term is especially used to refer to a sensation of emotional cleansing achieved through the contemplation of drama and other arts.

CAUSAL: A system of physical objects and forces in which the state of the system at any given time defines the state of the system at all future times. Machines are, ideally, causal systems: Each operation of the machine forces the next state of the machine to come into being, and only one next state is possible. Physicists are divided over whether the universe as a whole is a causal system. Causality—cause-and-effect—definitely operates at larger physical scales, but may not describe the action of atomic-scale events, which can in turn influence larger-scale (macro) events, as when a subatomic particle causes a mutation that influences the course of evolution. Whether subatomic events are truly random or truly causal is debated in quantum physics.

CAUTERY: The sealing off of a broken blood vessel during surgery by applying heat. The purpose is to minimize bleeding. Electrocautery—the use of an electrical tool for cautery—is common in modern surgery.

CELESTIAL MECHANICS: The study of the motions of celestial bodies such as planets, moons, and stars, moving in gravitational fields of force.

CELL CYCLE: Complete sequence of steps that must be performed by a cell in order to replicate itself, as seen from mitotic event to mitotic event. Most of the cycle consists of a growth period in which the cell takes on mass and replicates its DNA. Arrest of the cell cycle is an important feature in the reproduction of many organisms, including humans.

CELL MEMBRANE: The outer membrane of a cell, which separates it from the environment. Also called a plasma membrane or plasmalemma.

CELL WALL: A tough outer covering that overlies the plasma membrane of bacteria and plant cells.

CELLULAR RESPIRATION: The oxidation of food within cells, involving consumption of oxygen and production of carbon dioxide, water, and chemical energy in the form of ATP (adenosine triphosphate).

CEPHEIDS: Variable stars that can be used as standard candles.

CEREBELLUM: Latin for "little brain," the cerebellum is responsible for coordinating movement and balance. It occupies a place partially tucked under the forebrain's cerebral hemispheres. The cerebellum is extensively folded into parallel folds, or folia, giving it an appearance of having irregular pleats. The cerebellum possesses right and left hemispheres that are connected with the spinal cord and forebrain.

CEREBRAL: Of, or having to do with, the brain.

CEREBRAL CORTEX: The external gray matter surrounding the brain, made up of layers of nerve cells and fibers; it is thought to process sensory information and impulses.

CEREBRUM: The folded mass of nerve cells that sits over the rest of the brain and coordinates voluntary movements. It is also essential for memory, learning, and sensing things.

CETACEANS: Cetacea or cetaceans are an order of sea-dwelling mammals that includes whales, dolphins, and porpoises. They are hairless, breathe through a blowhole, spend their whole lives in the water, and are among the most intelligent animals.

CHAIN REACTION: A reaction in which a substance needed to initiate a reaction is also produced as the result of that reaction. With specific regard to a nuclear fission reaction, neutrons released during the reaction cause an ongoing series of fission reactions.

CHANDRASEKHAR LIMIT: In the early 1930s, Indian-American physicist Subrahmanyan Chandrasekhar (1910–1995) calculated the upper limit on star mass that can be supported by electron degeneracy pressure (the quantum-mechanical prohibition on energy-level sharing by electrons) against further gravitational collapse. A star remnant heavier than about 1.44 times the mass of our sun is beyond the Chandrasekhar limit and must collapse to form either a neutron star or black hole. Chandrasekhar was awarded a Nobel Prize in physics in 1983.

CHARGE: Describes an object's ability to repel or attract other objects. Protons have positive charges, while electrons have negative charges. Like charges repel each other while opposite charges, such as protons and electrons, attract one another.

CHEMOTHERAPY: The treatment of a disease or condition with chemicals that have a specific effect on its cause, such as a microorganism or cancer cell.

CHI: Chi or qi (pronounced "chee") is the life force supposed by traditional Chinese medicine and philosophy. There is no scientific evidence for the existence of chi.

CHIP LOG: A device (now obsolete) for measuring the speed of a surface vessel relative to the water. It consists of a small wooden board or chip that is attached to a line. The chip is cast overboard, where it drags in the water and is left behind by the motion of the ship. A line runs out for a fixed period of time, measured using an hourglass or other timepiece, giving a distance and time measurement that can be used to compute a velocity.

CHIRALITY: Also termed handedness, the quality of having non-superimposable mirror images.

CHLOROFLUOROCARBONS (CFCs): Chemical compounds containing chlorine, fluorine, carbon, and oxygen. They are widely used in refrigeration and air-conditioning systems and are destructive of the ozone layer in Earth's stratosphere.

CHROMATIC ABERRATION: A defect in the lens of refracting telescopes that results in a false color or blurring around the image. The problem arises because light of different wavelengths is focused at different distances from the lens.

CHRONOMETER: Any device that measures the passage of time. The term is especially used for accurate timepieces built for special purposes, such as navigation.

CHYMICAL: An obsolete spelling of "chemical," or having to do with chemistry.

CIRCUMNAVIGATE: Traveling completely around an object. It is possible to circumnavigate an island, a continent, or the entire world. Earth was first circumnavigated in the early 1500s by Portuguese sailors.

CITATION: In scholarly or scientific publication, a reference to or quotation of another work. The correct attribution of citations—explaining exactly where quotations have come from—is an essential aspect of modern scientific communication because it enables interested readers to trace ideas to their sources.

CLADISTICS: A method of determining evolutionary relationships based on evolutionary divergence; it is now used in many evolutionary disciplines.

CLADOGRAM: A diagram, resulting from a cladistic analysis, that depicts a hypothetical branching sequence of lineages leading to the taxa under consideration. The points of branching within a cladogram are called nodes. All taxa occur at the endpoints of the cladogram.

CLASSIFICATION SYSTEM: Any method of assigning a collection of objects, terms, creatures, or other things to a set of named categories or groups. In science, the best-known classification system is used in biology, which assigns every living creature to a unique place in a hierarchy of categories: variety, species, genus, family, order, class, phylum, kingdom, domain.

CLEAN WATER ACT: Any law that seeks to control water pollution may be referred to as a "clean water act." In the United States, the Federal Water Pollution Control Act of 1948 and its later amendments (1965, 1972, 1977, 1987) are the major body clean-water acts.

CLEAVAGE: The splitting of a rock or crystal along a natural smooth plane; that is, the stone cleaves along the plane. In biology, the term refers to the splitting of a cell during reproduction.

CLIMAX COMMUNITY: A relatively stable ecosystem characterized by large, old trees, marking the last stages of ecological succession.

CLONAL SELECTION THEORY: The theory that explains the basic workings of the adaptive immune system, which is the network of blood cells in vertebrates that fights infection and can produce immunity to some pathogens (disease-causing organisms). According to the theory, numerous cells called B cells circulate in the blood. Some B cells, called memory B cells, produce antibodies for specific antigens—that is, they produce Y-shaped molecules (antibodies) that attach to identifying molecules (antigens) on the surfaces of pathogens. Each individual B cell can produce only one kind of antibody. When an antigen for which some B cell already makes the right antibody appears in the body, many genetically identical copies (clones) of that B cell are made. This greatly increases the number of that type of antibodies being manufactured and, usually, defeats the infection before it can become harmful.

CLONING: A technique of genetic engineering in which an offspring is produced asexually (without joining egg and sperm) and has the exact same genes as its donor organism.

CO_2 LASER: Lasers are devices that produce beams of coherent light, that is, light whose photons are all aligned and of the same frequency and travel in the

same direction. Laser light can be produced from a variety of substances, one of which is carbon dioxide (CO_2). High power can be achieved affordably with a CO_2 laser, which emits ultraviolet light, so this type of laser is often used for high-power industrial applications such as welding. It can also be used in medicine.

COALSACK NEBULA: The Coalsack Nebula is a cloud of dark dust about 600 light years (3.5×10^{15} miles or 5.7×10^{15} km) from Earth and visible to the naked eye as a blot on the Milky Way (the part of our own galaxy that is visible in Earth's sky).

COASTAL: Of or having to do with a coast, that is, an edge of a landmass bordering an ocean.

CODON: A triplet of three letters representing bases of DNA. Also known as a triad; a group of three nucleotides in a DNA (deoxyribonucleic acid) or RNA (ribonucleic acid) molecule that during translation indirectly codes for the production of a single specific amino acid in a protein chain. More specifically, a section of DNA or RNA that codes for a single amino acid or for the termination of translation.

COHERENCE: In wave physics, coherence occurs when two or more waves—for example, light waves—traveling together have the same phase, that is, line up peak to peak and trough to trough.

COHORT: A group of people (or any species) sharing a common characteristic. Cohorts are identified and grouped in cohort studies to determine the frequency of diseases or disease outcomes over time.

COLLIDER (PARTICLE): A particle collider is a machine that accelerates (speeds up) atomic nuclei or subatomic particles such as protons to velocities approaching the speed of light. Particles are made to travel in either a straight line (in a linear collider) or a circle (in a ring collider) and eventually to collide with other particles, whether in a stationary target or a beam of particles traveling in the opposite direction. The goal is to produce high-energy collisions that spew out new particles whose interactions with surrounding detectors can be recorded. These particle showers reveal information about the physics of fundamental particles.

COMET: A small body composed of ice and dust that passes through the solar system, trailing a glowing plume or "tail" of gas as it nears the sun. Some comets follow a parabolic or hyperbolic path around the sun and disappear into deep space. Others follow highly elongated elliptical orbits and return at regular intervals. By convention, a short-period comet is one that returns at intervals of 200 years or less, and a long-period comet is one that returns at intervals greater than 200 years.

COMMENSALISM: In biology, a type of relationship between organisms that is intermediate between parasitism (or antibiosis) and symbiosis. In parasitism, one organism benefits and the other is harmed; in commensalism, one benefits and the other is neither harmed nor helped; in symbiosis, both organisms are helped.

COMMON RULE: A set of ethical guidelines for medical research in the United States that has been adopted by 18 federal agencies. All universities and hospitals hoping to receive U.S. government funding must adhere to the Common Rule guidelines, and most research adheres to them even if it is not federally funded. The Common Rule forbids certain kinds of human research altogether and requires meaningful, informed consent from subjects (with full freedom to decline participation) for those kinds of research that are permitted.

COMMUNITY: A collection of populations that interact with each other in the same geographic region.

COMPARATIVE ANATOMY: The study of the similarities and differences of the structure of living things.

COMPASS: A device for detecting the presence and direction of a magnetic field.

COMPETENCE: Competence, in medicine, refers to the ability of a structure to hold fluid without leaking. For example, an un-punctured stomach is competent. Restoring competence is of a goal of reconstructive surgery in the event of severe injuries.

COMPOUND MICROSCOPE: A multiple-lens microscope (two or more lenses housed in a long tube).

COMPOUND NUCLEUS REACTION: When an atomic nucleus is struck by a fast-moving particle, a nuclear reaction takes place. There are two types of reaction, namely, direct nucleus reaction and compound nucleus reaction. In a compound nucleus reaction, the particle is absorbed by the target nucleus and a new nucleus is formed; this new nucleus then proceeds to undergo radioactive decay (spontaneous breakdown).

CONCOMITANT: When two or more drugs are given together, as is the case in treating cancer or AIDS, the drugs are termed concomitant medications.

CONDENSATION: The process by which vapor molecules reform a liquid; a phase change from the gas state to the liquid state.

CONGENITAL MALFORMATIONS: Congenital features are those that people or other animals are born with; a congenital malformation or disorder is one that is present at birth.

CONJUGATE: In mathematics, the conjugate of a complex number is another number that has the same real part and a negative part of equal magnitude but opposite sign. The word "conjugate" has other technical uses in physics, chemistry, biology, and mathematics.

CONSERVATION BIOLOGY: The branch of biology that involves conserving rapidly vanishing wild animals, plants, and places.

CONTAGION: Transmission of an infectious disease from one person to another.

CONTINUOUS WAVE (CW): In physics, a continuous wave is one that oscillates regularly and continuously, without beginning, change, or ending. Absolutely continuous waves do not exist but are approximated, for engineering and science purposes, by waves that are unchanging for a relatively long period of time.

CONUNDRUM: Any difficult question, especially one expressed as a verbal puzzle.

CONVERGENT BOUNDARY: The boundary where two or more tectonic plates (large shell-like areas of rock floating on Earth's mantle, sometimes continental in size) drift against each other, edge to edge.

CONVERGENT EVOLUTION: The evolution of a similar feature in separate species is termed convergent evolution. For example, the shapes of sharks and dolphins evolved convergently; no shared or common ancestor of these two families of species had such a shape.

COPENHAGEN INTERPRETATION: A way of viewing the equations of quantum mechanics. Its earliest proponents were Danish physicist Neils Bohr (1885–1962) and German physicist Werner Heisenberg (1901–1976), who worked together on quantum mechanics in Copenhagen, Denmark, in the late 1920s. According to the Copenhagen interpretation, the wave function that describes every particle's probability of being found in any given place is collapsed by measurement—that is, it is reduced from an infinite number of possibilities to a single, definite state. Other interpretations of quantum mechanics say that the wave function does not collapse, but continues to hold all its values in a state of superposition (all-at-onceness or layered being). In this theory, an infinite number of co-existing universes are being continually generated by all the particle interactions in the universe. The majority of modern physicists today affirm the Copenhagen interpretation, but a growing minority affirms the many-worlds interpretation.

CORPUSCULARIANISM: A physical theory propounded by some medieval alchemists who said that all objects are made of invisibly small units or corpuscles similar to atoms. English physicist Isaac Newton (1643–1727) employed a version of corpuscularianism when he developed his theory of light as a stream of particles.

CORTISOL: A hormone produced in the cortex of the adrenal gland. Its artificial form, hydrocortisone, is used to relieve inflammation from allergic reactions, such as exposure to poison ivy, and the like.

COSMIC MICROWAVE BACKGROUND (CMB): A bath of low-intensity radio waves that shines from all parts of the sky. It is the afterglow of the big bang, the beginning of time and the universe in a state of extremely high density about 13.7 billion years ago. The CMB was predicted by big bang theory before being detected. Slight variations in its intensity from one part of the sky to another were later predicted by the inflation version of big bang theory and have been confirmed in recent years by satellite observations. The CMB is one of the most important pieces of evidence for the big bang.

COSMIC RAY: The fast-moving particles (protons, electrons, and helium nuclei) coming from outer space and moving near the speed of light with which Earth is constantly struck. Most cosmic rays originate near extremely heavy objects, such as black holes and neutron stars, that are accelerating nearby matter. Most of the matter accelerated near these objects gets sucked in, but some gets slung out: Some of these particles become cosmic rays.

COSMOGONY: The study of the origin of the solar system or (usually) of the universe as a whole. In modern science, cosmology (the study of the properties universe as a whole) includes cosmogony.

COSMOLOGY: The study of the universe as a whole, its nature, and the relations between its various parts.

COSMOS: All that exists, considered as a single, structured thing, from the Greek word meaning both "order" and "ornament." In modern usage, the word is a synonym for universe.

COULOMB FORCE: In the 1780s, French physicist Charles de Coulomb (1736–1806) announced a

simple mathematical law describing the force of attraction or repulsion between two electrical charges: charges of opposite sign (positive, negative) exert a pull on each other, while charges of same sign exert a push against each other. This pull or push is termed the Coulomb force.

COVALENT: In chemistry, a covalent bond between two atoms is produced when the atoms share one or more electrons. The other major type of chemical bond is ionic, in which atoms lacking electrons or endowed with extra electrons (and thus having positive or negative charges, respectively) are attracted to each other.

CREATION SCIENCE: A form of creationism, the belief that life, or at least some life or features of life, was created miraculously rather than by natural evolutionary processes. Creation science was developed after the U.S. Supreme Court ruled in *Epperson v. Arkansas* (1968) that all U.S. state laws banning the teaching of evolutionary biology were unconstitutional. In response, creationists developed creation science, a pseudoscientific set of claims asserting that the Genesis story of creation, taken literally, is supported by scientific evidence (it is not). In 1987, the Supreme Court ruled in *Edwards v. Aguillard* that creation science is religious doctrine, not science, and cannot be taught in U.S. public schools because the First Amendment to the U.S. Constitution forbids the furtherance by government of any religion.

CRETINISM: An obsolete term for the symptoms of severe thyroid deficiency, including mental retardation.

CRITICAL MASS: The minimum amount of fissionable uranium or plutonium that is necessary to maintain a chain reaction.

CROSS SECTION: A slice, or slice-like view, that reveals the interior of an object. Cutting an apple in half, for example, reveals a cross section of the apple to view. In medicine, an interior view using "slices" can be constructed by an imaging instrument.

CROSS STAFF: A cross-shaped instrument for determining the angular height of the sun or other heavenly body above the horizon. The user places one eye at one end of the long stick and aligns it with the horizon, then shifts a shorter cross-piece along the long stick until its upper end is aligned with the object being observed. The angular height of the object can then be read off from markings on the long stick.

CRUSADES: A series of military expeditions undertaken by European nations, mostly against the area centered on Jerusalem, from about AD 1100 to about 1300. Religious motives were usually proclaimed for Crusades, hence their name (from "crucifix" or cross).

CRYSTAL: Naturally occurring solid composed of atoms or molecules arranged in an orderly pattern that repeats at regular intervals.

CRYSTALLINE: Having a regular arrangement of atoms or molecules; the normal state of solid matter.

CULTURAL REVOLUTION: A period of government-mandated social upheaval in China from 1966 to 1976. Its proclaimed purpose was to solidify the Communist Revolution by purging it of old habits, old culture, old ideas, and old customs. Religion was persecuted; science and education were severely set back; and several million deaths were caused, both by direct killings and disruption of agriculture and the economy.

CUNEIFORM: One of the earliest forms of writing. It was developed by the Sumerian civilization in the area now known as southern Iraq in about 3000 BC. Cuneiform was inscribed in clay bars or pads called tablets by pressing a sharpened reed into wet clay. The clay later hardened, making a permanent document (tens of thousands still exist). The reed's sharpened end made a series of wedge-shaped dents in the wet clay to denote characters of the script, hence the term "cuneiform" (from the Latin *cuneus*, wedge).

CYCLONE: An area of low pressure in which winds blow counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

CYTOKINES: A class of substances secreted by certain cells in order to signal to other cells. In the vertebrate immune systems, one of the functions of cytokines is to attract white blood cells to infected tissue in order to combat invading pathogens (e.g., viruses or bacteria).

CYTOPLASM: The semifluid substance inside a cell that surrounds the nucleus and other membrane-enclosed organelles.

CYTOTOXICITY: The toxicity (poisonousness) of a substance to living cells. Some medications, such as those used in chemotherapy for cancer, can only be given in certain maximum doses because of their cytotoxicity.

D

DARCY'S LAW: A mathematical statement of how liquids flow through sand and other porous (hole-filled) substances. It is named after French scientist Henry Darcy (1803–1858).

DARK ENERGY: In 1998, astronomers discovered that the universe is not only expanding, but expanding faster all the time (accelerating). Since energy is required to accelerate an object, it followed that some form of energy must be driving the accelerated expansion. Scientists do not know the nature of this energy and have not, as of 2008, been able to observe any source for it, and so have dubbed it "dark energy" until a better understanding is obtained. Dark energy makes up about 74% of the material of the universe.

DARK MATTER: Unseen matter that has a gravitational effect on the motions of galaxies within clusters of galaxies.

DATUM (PLURAL: DATA): A single number resulting from a measurement is a datum; the plural of datum is data.

DEAD RECKONING: A navigational method of estimating one's location after a period of movement, based on earlier knowledge of one's position and knowledge of the direction and rate of travel. By adding a change vector to a known position, a new position can be calculated. Highly precise dead reckoning is used in inertial-guidance systems, which are initialized with precise location information and then measure all changes in velocity that they undergo by measuring the forces accelerating them. Inertial guidance systems are used in many guided missiles, aircraft, and spacecraft.

DECAY RATE: The rate of the radioactive decay process for a given radioactive substance. Atoms of any particular radioactive type tend, on average, to undergo spontaneous fission (breaking up of their nuclei) at a certain rate, as measured in fissioning atoms per unit of time.

DEDUCTION: A form of logical reasoning. In deduction, one reasons from general laws or principles to particular facts. For example, knowing that a stone has been dropped at a certain time and place and knowing the law of gravitation, one can deduce when the stone will strike the ground. The complementary or reverse form of reasoning is induction, which reasons from particular observations to general principles. For example, after making measurements of how dropped stones accelerate, one might induce the law of gravitation.

DEEP TIME: Until the 1700s, few thinkers in the Western world considered the possibility that Earth (or the universe as a whole) might be extremely old relative to human history—say, many million or perhaps many billions of years old, rather than 10,000 or so years old. In the late 1700s and early 1800s, however, geologists found convincing evidence that Earth was extremely old. The phrase "deep time" became popular in the late twentieth century to describe the vast extent of past time.

DEFERENT: In the Ptolemaic system of astronomy, the circular path that the center of an epicycle follows around Earth. In this system, used in Europe from the second century AD until the Copernican revolution in the 1500s, the motions of the planets relative to those of the fixed stars were explained by compounded circular motion: that is, the planets were said to move in circles around points that moved in circles around Earth. A deferent was a circle traced around a point in space near Earth called the equant; around the point tracing the circle was another circle, the epicycle, along which the planet moved. The combination of these motions imparted a complex motion to planets that accounted for their movements in the sky.

DEISM: A form of monotheism (belief in one God) that rejects the idea that God might be directly involved in the workings of the universe. According to deism, God created the universe but has since then allowed it to unfold entirely according to its own internal laws.

DELAYED TYPE HYPERSENSITIVITY (DTH): A form of tissue damage that can result from the action of the body's immune system. An aspect of the immune system termed cell-mediated immunity increases the tendency of certain white blood cells (T lymphocytes) to attack pathogens. When these white blood cells attack cells in the body, often skin cells, the result is DTH. DTH can be triggered by viruses, fungi, bacteria, medications, or chemicals such as nickel, with results that vary from person to person.

DELTA: Triangular-shaped area where a river flows into an ocean or lake, depositing sand, mud, and other sediment it has carried along its flow.

DEMIURGE: In some ancient theological systems, a secondary supernatural being (inferior to God) who is responsible for creating the universe.

DEOXYRIBONUCLEIC ACID (DNA): A double-stranded molecule joined together by bonds between base pairs. The strands are akin to the sides of a ladder and the base pairs the steps of the ladder; the molecule as a whole is helical (shaped as a gently twisted ladder). DNA is the carrier of genetic information (encoded in the specific series of base pairs) for almost all organisms, though some viruses use ribonucleic acid (RNA).

DEPLETION REGION: In integrated electronic circuitry, devices that control the flow of current in response to a control voltage (transistors), much as a valve controls the flow of water through a faucet, are made by mixing contaminant substances into parts of a solid crystal of silicon or other semi-conducting materials. These contaminants either donate extra electrons to the crystal matrix (add a negative charge) or are short of electrons (add a positive charge). Where a portion of the crystal with extra electrons touches a portion lacking electrons, some of the extra electrons are pulled over from the negatively-charged area to the positively-charged area; this continues until electrical forces are balanced. When a balanced state is achieved, an in-between layer exists that is neither positively nor negatively charged and so lacks carriers for current. This area, depleted of charge carriers, is termed a depletion region.

DEPRESSION: In psychology and medicine, a mental disorder characterized by hopelessness, unhappiness, and kindred feelings that are more severe than circumstances would warrant (e.g., a person who is sad because a loved one has died is not suffering from depression, whereas a healthy, functional person who is so unhappy that they are considering suicide may be suffering from depression). In economics, a prolonged period of reduced economic activity, worse than a recession.

DEPTH OF FIELD: In photography, depth of field refers to the range of distance from the lens in which objects are in focus. A shallow depth of field means that only objects at or near a specific distance are in focus; a deep depth of field means that objects over a wide range of distances are in focus.

DETERMINATION: In biology, determination of sex is usually by genetic inheritance: in human beings, for example, males inherit one X chromosome and one Y chromosome, while females inherit two X chromosomes. (There are a number of exceptions to this rule, but this is usually the case.)

DETERMINISM: The notion that a known effect can be attributed with certainty to a known cause.

DETERMINISTIC SYSTEM: A deterministic or causal system is a system of physical objects in which the state of the system at any given time defines or determines the state of the system at all future times. Machines are, ideally, deterministic systems: Each operation of the machine forces the next state of the machine to come into being, and only one next state is possible. Physicists are divided over whether the universe as a whole is deterministic; large-scale events are deterministic, a quality we rely on in designing machines, but whether subatomic events are truly random or truly deterministic is debated in quantum physics.

DICHOTOMY: Any division into two clearly-separate categories. For example, to classify all cells as eukaryotic or prokaryotic is to make a dichotomy.

DIFFERENTIATE: With regard to cells, a change into a more specialized cell type.

DIFFERENTIATION: In developmental science, the process by which cells mature into specialized cell types, such as blood cells, muscle cells, brain cells, and sex cells.

DIFFRACTION GRATING: A device consisting of a surface into which are etched very fine, closely spaced grooves that cause different wavelengths of light to reflect or refract (bend) by different amounts.

DIGITAL: The opposite of analog; it is a way of showing the quantity of something directly as digits or numbers.

DIODE: An electronic device that permits current to flow through itself in one direction but not in the other.

DIPLOID: Having two sets of chromosomes.

DISSECTION: Cutting and separating the body along its natural cleavage lines to allow scientific examination.

DISTILLATION: The process of separating liquids from solids or from other liquids with different boiling points by a method of evaporation and condensation, so that each component in a mixture can be collected separately in its pure form.

DIVERGENT BOUNDARY: Where two or more tectonic plates (large shell-like areas of rock floating on Earth's mantle, sometimes continental in size) are forced apart by the creation of new crust from below (as along the Atlantic midocean ridge) or pulled apart by plate motion (as in the Great Rift Valley of Africa), the boundary between the two plates is termed a divergent boundary.

DIVINATION: Any attempt to foresee the future using magical or supernatural means. Many ancient religions practiced forms of divination, and some religions still do. Attempts to read future events in random or pseudorandom patterns such as the internal organs of sacrificed animals, the positions of tea-leaves, and so forth are all forms of divination.

DOMINANCE: In genetics, dominance is a quality of certain genes. Every cell possesses two versions

of every gene, such as the gene for eye color. If the genes are alike (say, both are for blue eyes), then the character coded for by the gene will definitely appear in the organism. If the genes are unlike (say, one copy of the eye-color gene is for brown eyes and the other is for blue eyes), then the outcome will be determined by whether one of the genes is dominant. If one of the genes is dominant, it will dominate or force the outcome regardless of what the other gene is. In the case of eye color, the gene for brown eyes is dominant: a child will have brown eyes even if only one of its eye-color genes is a brown-eyes gene. To have blue eyes, a child must have two copies of the gene for blue eyes. The gene for blue eyes is an example of a recessive gene, as opposed to a dominant gene.

DOPANT: An impurity added to a semiconducting material.

DOPING: The act of adding impurities (dopants) to change semiconductor properties. In athletics, the illegal use of steroids, drugs, hormones, or techniques such as blood doping (injecting previously drawn red blood cells to increase oxygen) in order to enhance athletic performance.

DYNAMICAL SYSTEM: In mathematics, any equation or set of equations that describes the changing of a system over time—in particular, the location of a certain point in the system, such as the tip of a pendulum or a particle suspended in a swirling fluid.

E

ECLIPTIC: The plane in which the orbits of the planets and asteroids in our solar system lie.

ECOSYSTEM: Any natural unit or entity including living and non-living parts that interact to produce a stable system through cyclic exchange of materials.

EL NIÑO: A warming of the surface waters of the eastern equatorial Pacific that occurs at irregular intervals of 2–7 years, usually lasting 1–2 years. Along the west coast of South America, southerly winds promote the upwelling of cold, nutrient-rich water that sustains large fish populations, which then sustain abundant sea birds, whose droppings support the fertilizer industry. Near the end of each calendar year, a warm current of nutrient-pool tropical water replaces the cold, nutrient-rich surface water. Because this condition often occurs around Christmas, it was named El Niño (Spanish for boy child, referring to the Christ child). In most years the warming last only a few weeks or a month, after which the weather patterns return to normal and fishing improves. However, when El Niño conditions last for many months, more extensive ocean warming occurs and economic results can be disastrous. El Niño has been linked to wetter, colder winters in the United States; drier, hotter summers in South America and Europe; and drought in Africa.

ELECTRIC FIELD: An invisible physical influence that exerts a force on an electric charge. All electric charges produce electric fields. Magnetic fields that are changing (getting weaker or stronger) also produce electric fields.

ELECTROCARDIOGRAPHY: When a heart contracts, electrical fields are created as ions (charged atoms) that flow in and out of muscle cells. These electrical fields can be sensed as voltages on the surface of the body. Electrocardiography is the recording of these changing voltages over time as the heart beats, measured at certain standard points on the skin. The resulting visual collection of what looks like squiggly lines is an electrocardiogram. Cardiologists can diagnose many disorders of the heart simply by looking at an electrocardiogram.

ELECTROCONVULSIVE SHOCK THERAPY: Also known as electroshock. A treatment in which an electrical current is made to flow briefly through the brain, triggering a seizure. It is used as a treatment for severe depression and for severe forms of some other mental illnesses.

ELECTROMAGNETIC FORCE: Electrically charged particles experience a force when they are in the presence of an electrical field, whether they are moving or stationary; they also experience a force in the presence of a magnetic field, if they are in motion. These forces are manifestations of a single fundamental force, the electromagnetic force.

ELECTROMAGNETIC RADIATION: Radiation that has properties of varying electric and magnetic waves and that travels through a vacuum with the speed of light. X rays, ultraviolet light, visible light, microwaves and radio waves are examples of electromagnetic radiation differing only in their wavelengths (or frequency).

ELECTROMAGNETIC SPECTRUM: The entire range of radiant energies or wave frequencies from the longest to the shortest wavelengths—the categorization of solar radiation. Satellite sensors collect this energy, but what the detectors capture is only a small portion of the entire electromagnetic spectrum. The spectrum usually is divided into seven sections: radio, microwave, infrared, visible, ultraviolet, x-ray, and gamma-ray radiation.

ELECTROMAGNETIC WAVE: Method of travel for radiant energy, so called because radiant energy has both magnetic and electrical properties. Electromagnetic waves are produced when electric charges change their motion. Whether the frequency is high or low, all electromagnetic waves travel at 186,411 miles/second (300,000,000 meters/second).

ELECTROMAGNETISM: A form of magnetic energy produced by the flow of an electric current through a metal core. Also, the study of electric and magnetic fields and their interaction with electric charges and currents.

ELECTRON: A subatomic particle having a charge of −1.

ELECTRON MICROSCOPE: A microscope that uses a beam of electrons to produce an image at very high magnification.

ELECTROPHORESIS: The use of electrical fields to separate molecules of different sizes. Electrophoresis is a form of chromatography.

ELECTROWEAK FORCE: In physics, the single unified force of which the electromagnetic force and weak interaction are both manifestations. The electromagnetic force is caused by an electromagnetic field; the weak interaction is involved in certain types of radioactive decay (e.g., beta decay of neutrons).

ELEMENT: Substance consisting of only one type of atom.

ELEMENTARY PARTICLE: A subatomic particle that cannot be broken down into any simpler particle.

ELLIPSE: A two-dimensional figure defined in relation to two points called foci. If A and B are the foci of an ellipse, and X is a point on that ellipse, then the sum AX + BX will be the same for every point X.

ELLIPSOID: An egg-like three-dimensional shape defined by rotating an ellipse in space. In geodesy (measurement of Earth or other planetary bodies), the ellipsoid is the idealized, simplified shape of the planet. Features of the actual planet's shape are defined by their distances from the ellipsoid.

EMBRYO: The earliest stage of animal development in the uterus before the animal is considered a fetus.

EMBRYONIC STEM CELL: A stem cell found in embryos about a week old. Descendants of one of these cells can become any kind of tissue. These cells can reproduce indefinitely in the laboratory.

EMISSION LINE: An atom or molecule emits photons (light particles) when its electrons jump from higher to lower electron levels. These photons, depending on the magnitude of the jumps possible in that atom or molecule, have certain specific energies. When displayed as a spectrum, these emissions, at certain favored frequencies, appear as spikes or vertical lines—emission lines.

EMPIRICISM: The philosophical doctrine, first developed in the 1600s and 1700s, that all knowledge arises from sense impressions—things seen, heard, felt, and so on. It opposes the view that some knowledge is available to the mind *a priori*, that is, by the very nature of thought.

ENDEMIC: Present in a particular area or among a particular group of people.

ENDOCRINE SYSTEM: The collection of glands—small, diverse organs located in the head and torso—that release substances into the blood termed hormones. Hormones influence growth, sex and reproduction, mood, and other aspects of physiology.

ENDOPLASMIC RETICULUM: The network of membranes that extends throughout the cell and is involved in protein synthesis and lipid metabolism.

ENDOTHERMIC: Reaction that absorbs heat from its surroundings as the reaction proceeds.

ENERGY: The ability to do work or transfer heat.

ENLIGHTENMENT: An eighteenth-century movement that advocated reason and scientific discovery as the bases of intellectual authority.

ENTROPY: Measure of the disorder of a system.

ENVIRONMENTAL GEOGRAPHY: A subdiscipline of geography that emphasizes the relationship of human beings to their environment, with an emphasis on spatial relationships and resource use.

ENVIRONMENTAL PROTECTION AGENCY (EPA): An agency of the U.S. federal government that was formed in 1970 and charged with defining and enforcing regulations that protect the environment (water, air, forests, shores, wetlands, wild animals, etc.). Some other nations have agencies with similar names or functions.

ENZYME: Any of numerous complex proteins produced by living cells that act as catalysts, speeding up the rate of chemical reactions in living organisms.

EPICYCLES: In the Ptolemaic system of astronomy used in European science from the second century

AD until the Copernican revolution in the 1500s, the motions of the planets relative to those of the fixed stars were explained in terms of compounded circular motion: That is, the planets were thought to move in circles around points that moved in circles. A deferent was a circle traced around a point in space near Earth called the equant; around the point tracing the circle was another circle, the epicycle, along which the planet moved. The combination of these motions imparted a complex motion to planets that accounted for their movements in the sky.

EPIDEMIC: Rapidly spreading outbreak of a contagious disease.

EPIDEMIOLOGY: The study of the causes, distribution, and control of disease in populations.

EPIGENESIS: The development of an animal or plant from a single fertilized egg cell. In modern biology, the term refers to this whole process of development, including the specialization of various tissues; formerly, it distinguished this theory of development from the theory of preformationism, which was the idea that all living things begin as extremely small copies of themselves and simply get bigger as they develop.

EQUANT: In the Ptolemaic system of astronomy the motions of the planets relative to those of the fixed stars were explained in terms of compounded circular motion: that is, the planets were thought to move in circles around points that moved in circles. A deferent was a circle traced around a point in space near Earth called the equant, an arbitrary point inside a planet's orbit.

EQUATOR: The line circling a planet that divides it into northern and southern hemispheres (halfspheres). An imaginary plane passing through the planet's center and at right angles to its axis of rotation will intersect the planet's surface along its equator.

EQUILIBRIUM: When the reactants and products of a chemical reaction are in a constant ratio. The forward reaction and the reverse reaction occur at the same rate when a system is in equilibrium.

EROSION: Processes (mechanical and chemical) responsible for the wearing away, loosening, and dissolving of materials, particularly of Earth's crust.

ERYTHROCYTES: Also known as red blood cells, erythrocytes contain the pigment hemoglobin; the characteristic red color of blood is due to the erythrocytes, which have the remarkable capacity to combine with and release oxygen. Human red blood cells contain a 33% solution of hemoglobin. Oxygen is transported to living tissues of the body as oxyhemoglobin in red blood cells. The human red blood cell is a biconcave disc with an average of about a 0.0003 inch (0.008 mm) diameter. Erythrocytes are the most common cell type in blood (with an average of about 5,500,000 per ml in men and 5,000,000 per ml in women). Newborn babies have an even greater number of erythrocytes, with as many as 7,000,000 per ml. Red blood cells are suspended in plasma, which is the straw colored liquid part of the blood. Human, and most mammalian, erythrocytes have nuclei while they develop in the bone marrow.

ESCAPE VELOCITY: The escape velocity of a planet, asteroid, moon, or other object is the minimum initial velocity that must be imparted to a projectile (e.g., a bullet) at its surface if that object is to leave the vicinity of the planet or other object completely and permanently. Escape velocity is calculated on the presumption (false, in the case of Earth and some other planets) that there is no atmosphere to get in the way.

ESTRUS: In many mammalian species, for example dogs, females go through a regular period of enhanced fertility and sexual willingness; this period is termed estrus.

ESTUARY: Lower end of a river where ocean tides meet the river's current.

ETHANOL: Compound of carbon, hydrogen, and oxygen (CH_3CH_2OH) that is a clear liquid at room temperature; also known as drinking alcohol or ethyl alcohol. Ethanol can be produced by biological or chemical processes from sugars and other feedstocks and can be burned as a fuel in many internal-combustion engines, either mixed with gasoline or in pure form. Several governments, most notably in Brazil and the United States, encourage the production of ethanol from corn, switchgrass, algae, or other crops to substitute for imported fossil fuels. Ethanol is criticized by some as being based on environmentally destructive agriculture, putting human populations into competition with automobiles for the produce of arable land and providing little more energy (depending on the manufacturing process used) than is required to produce it.

ETHER: Also spelled aether; the medium that was once believed to fill space and to be responsible for carrying light and other electromagnetic waves.

ETHOLOGIST: A scientist who studies human behavior in terms of its biological influences and consequences.

ETHOLOGY: The scientific and objective study of the behavior of animals in the wild rather than in captivity. Also, the study of the formation of human character.

EUCLIDEAN GEOMETRY: A type of geometry based on certain axioms originally stated by Greek mathematician Euclid (c.325–c.270 BC).

EUKARYOTE: Multicellular organism whose cells contain distinct nuclei and membrane-bound structures called organelles.

EVENT HORIZON: A spherical surface around any black hole that is a boundary separating the vicinity of the black hole from the rest of the universe. Light cannot travel from inside the event horizon to outside; therefore, events inside the event horizon cannot be seen on the outside (hence the term "event horizon," as one cannot see what is over a horizon).

EVOLUTION: The theory that all plants and animals developed gradually from earlier forms over a long period of time and that variations within a species are the result of adaptive traits passed on from generation to generation.

EXOGAMY: The practice of always marrying outside a certain group, such as one's own village.

EXONERATE: To prove someone innocent.

EXOTHERMIC: Reaction that gives off heat to the environment as the reaction proceeds.

EXPLANANDUM: A phenomenon, in science, for which an explanation is sought. The explanation is termed an explanans.

F

FALSIFIABILITY: A claim is falsifiable if there is, at least in principle, some way of proving that the claim is false. For example, the claim that gravity obeys an inverse-square law is falsifiable (has falsifiability): One can conduct tests and see what kind of law gravitation obeys and whether it is in fact an inverse-square law. However, the claim that all life is a dream, or that God created the universe five minutes ago complete with all our memories of a deeper past, is not falsifiable: All possible evidence could be part of the dream or could have been created along with everything else. Most scientists agree that although falsifiability is not enough to make a claim scientific, to be scientific a claim must be falsifiable.

FALSIFIABLE: A theory or claim is falsifiable if there are reasonably possible conditions under which the theory or claim can be proved false. To be scientific, an idea must be falsifiable (though it takes more than falsifiability to make an idea a scientific one).

FAT: A type of lipid, or chemical compound, used as a source of energy, to provide insulation, and to protect organs in an animal body.

FATTY ACIDS: Carboxylic acids found in fats and oils; there are many varieties of fatty acid. Chemically, all consist of a hydrocarbon chain terminated by a carboxyl group (CO_2H).

FERMENTATION: Chemical reaction in which enzymes break down complex organic compounds (for example, carbohydrates and sugars) into simpler ones (for example, ethyl alcohol).

FIBER: A long, threadlike material, often used in the manufacture of cloth. Also, in terms of composite fillers, a fiber is a filler with one long dimension. In nutrition, the portion of food that remains undigested by physiological processes but that is essential to facilitate digestion and intestinal health. Fiber is also described as bulk or roughage. Fiber may be soluble (able to dissolve in water) or insoluble, natural or synthetic.

FIBER OPTICS: The use of glass threads or fibers to carry light rays.

FIELD EFFECT TRANSISTOR (FET): A transistor is an electronic device that controls a current flow in response to a separate electrical signal, like a valve regulating the flow of water through a faucet. A field-effect transistor (FET) accomplishes this by using an electrical field to pinch a conducting volume of semiconductor crystal; the stronger the field, the narrower the conducting zone and the higher its resistance (i.e., less current flows). Most of the transistors used in modern integrated circuits such as microprocessor chips are FETs.

FISSION: Splitting or breaking apart. In biology, the division of an organism into two or more parts, which each produce a new organism. Nuclear fission is a process in which the nucleus of an atom splits, usually into two daughter nuclei, with the transfor-

mation of tremendous levels of nuclear energy into heat and light.

FLYBY: A type of mission in which an unmanned spacecraft passes close to a planet without landing or going into orbit.

FOCAL LENGTH: In optics, the distance between the center of a focusing mirror or lens is the focal length of that mirror or lens.

FOMITE: An object or a surface to which infectious microorganisms such as bacteria or viruses can adhere and be transmitted. Transmission is often by touch.

FOOD CHAIN: A sequence of organisms, each of which uses the next lower member of the sequence as a food source.

FORCE: Any external agent that causes a change in the motion of a free body or that causes stress in a fixed body.

FORENSIC SCIENCE: A multidisciplinary subject used for examining crime scenes and gathering evidence to be used in prosecution of offenders in a court of law. Forensic science techniques are also used to examine compliance with international agreements regarding weapons of mass destruction.

FORMALISM: A theory of the nature of mathematics proposed by German mathematician David Hilbert (1862–1943). According to formalism, mathematics does not refer to abstract objects or to physical reality, but only to certain logical forms—namely, the forms of mathematical statements themselves (hence the term formalism). Mathematics, on this view, is a system of statements whose only real content is their form. Pure formalism was ruled out by Gödel's incompleteness theorem in 1931.

FOSSIL: Hardened remains or traces of plant or animal life from a previous geological period preserved in Earth's crust.

FOUNDATIONAL CRISIS: In the early twentieth century, a vigorous debate arose among mathematicians over what the nature of mathematics itself is. This debate has been termed the foundational crisis.

FOUNDATIONAL THEORY: In mathematics, any philosophical explanation of the nature or basic foundations of mathematics itself.

FRACTAL: A fractal is a geometric pattern in which each part of the pattern has the same character as the total pattern. Some natural patterns, such as fern branching, have a nearly fractal character; approximately fractal patterns are also used in some technological applications, such as cell-phone antennas.

FRAUNHOFER LINE: Light from the sun, displayed as a spectrum (a plot showing intensity or brightness over a range of frequencies), features a number of narrow notches. These notches or lines, named after German physicist Joseph von Fraunhofer (1787–1826), who discovered them in 1802, are frequencies of comparatively low intensity light that atoms in the atmosphere of the sun absorb. In effect, they are colors of light that are emitted from the sun's interior but that the sun's atmosphere filters out before they can be radiated into space.

FREQUENCY: The rate at which vibrations, oscillations, or events take place over time. In characterizing light, frequency is expressed in cycles per second or in hertz (Hz) to describe the number of wave crests that pass a given point in a given period of time.

FRONT: A boundary between two different air masses. The difference between two air masses is sometimes unnoticeable, but when the colliding air masses have very different temperatures and amounts of water in them, turbulent weather can erupt.

FUNDAMENTAL THEOREM OF CALCULUS: In calculus, the two fundamental operations are integration (finding the area under a curve) and differentiation (finding the slope of a curve at a single point). The fundamental theorem of calculus is that these two operations are inverses of each other: Integrating a function can be undone by differentiating the result, and vice versa.

FUSION: The process stars use to produce energy to support themselves against their own gravity. Nuclear fusion is the process by which two light atomic nuclei combine to form one heavier atomic nucleus. As an example, a proton (the nucleus of a hydrogen atom) and a neutron will, under the proper circumstances, combine to form a deuteron (the nucleus of an atom of "heavy" hydrogen). In general, the mass of the heavier product nucleus is less than the total mass of the two lighter nuclei. Nuclear fusion is the initial driving process of nucleosynthesis.

G

GALAXY: An isolated system of stars and gas held together by its own gravity.

GAMETE: A male or female reproductive cell.

GAMMA RAY: Short-wavelength, high-energy radiation formed either by the decay of radioactive elements or by nuclear reactions.

GENE: A segment of a DNA (deoxyribonucleic acid) molecule contained in the nucleus of a cell that acts as a kind of code for the production of some specific protein. Genes carry instructions for the formation, functioning, and transmission of specific traits from one generation to another.

GENERAL RELATIVITY: In 1915, German-American physicist Albert Einstein (1879–1955) announced a mathematical theory that described the nature of gravitation by appeal to the curvature of space and time. This theory, general relativity, has been one of the most successful scientific theories of all time and has passed many rigorous observational tests by successfully predicting the precise behaviors of various experimental setups and distant astronomical objects.

GENETIC ENGINEERING: The process of manipulating specific genes of an organism to produce or improve a product or to analyze the genes.

GENETIC FINGERPRINTING: The use of DNA from individual people or other creatures to tell them apart. Except for identical multiple births (e.g., identical triplets) and a few other exceptional cases, every multicellular organism has unique DNA.

GENETICALLY MODIFIED FOODS: Foods derived from plants or animals whose DNA has been altered technologically, usually by inserting genes.

GENOME: All of the genetic information for a cell or organism. The complete sequence of genes within a cell or virus.

GENOTYPE: The genetic information that a living thing inherits from its parents that affects its makeup, appearance, and function.

GENUS (PLURAL: GENERA): Biologists class living things into groups; for instance, all wolves are members of a single species. Wolves, coyotes, dingoes, and jackals, which are all closely related through evolutionary descent, are classed into a single group called a genus: in this case, the genus *Canis*. Genera (of which there are thousands) are lumped into families. From there on up, the classification system recognizes order, class, phylum, kingdom, and domain.

GEOCENTRIC: A geocentric model of the solar system places a stationary Earth at the center of the solar system, with the sun and planets orbiting Earth.

GEOCENTRISM: The discarded theory that a stationary Earth lies at the center of the universe (or solar system).

GEOCHRONOLOGY: The determination of the absolute ages of rocks and other natural deposits. The basic tool of geochronology is radiometric dating, which measures the amounts of radioactive elements and their daughter isotopes in samples. The relative proportions of these atomic varieties reveal the sample's age.

GEOGRAPHY: Geography is the scientific study of the surface of Earth, including the interactions of landscapes, bodies of water, the atmosphere, human beings, plants, and animals.

GEOID: A surface of constant gravitational potential around Earth; an averaged surface perpendicular to the force of gravity.

GEOLOGIC COLUMN: An idealized assemblage of all the rock layers deposited throughout Earth's history. Only fragments of the total column exist in any one location (with possible rare exceptions), due to uneven episodes of erosion that have removed rather than deposited layers; however, by comparing overlapping segments of the column found in different places, geologists can describe the entire column. Geochronology is used to assign absolute dates to the various layers of the column.

GEOLOGIC RECORD: Evidence of Earth's history left in rocks and sediments over thousands to billions of years. Events that can be inferred from the geological record include climate changes, biological evolution, continental drift, and asteroid impacts.

GEOMETRIC ISOMERS: Stereoisomers in molecules with restricted rotation about a bond.

GLAND: A small organ that produces a hormone, a substance released into the blood that affects behavior, sex and reproduction, growth, and other body functions. Some of the glands in the human body are the testes, ovaries, thyroid gland, and pituitary gland.

GLOBAL WARMING: Warming of Earth's atmosphere that results from an increase in the concentration of gases that store heat, such as carbon dioxide.

GLOBULAR CLUSTER: A spherical collection of stars that appears cloudy to the naked eye.

GLUCOSE: Also known as blood sugar; a simple sugar broken down in cells to produce energy.

GLUON: The elementary particle thought to be responsible for carrying the strong force (which binds together protons and neutrons in the atomic nucleus).

GLYCOLYSIS: A series of chemical reactions that takes place in cells by which glucose is converted into pyruvate.

GLYCOPROTEIN: A membrane-bound protein that has attached branching carbohydrates. These may function in cell-cell recognition, such as in human blood groups and immune system response, as well as in resisting compression of cells.

GNOMON: The pointer that casts a shadow on a sundial.

GRADUALISM: A model of evolution that assumes slow, steady rates of change. Charles Darwin's (1809–1882) original concept of evolution by natural selection assumed gradualism. Contrast with punctuated equilibrium.

GRAND UNIFIED THEORIES (GUTs): Systems of physical laws that describe the strong nuclear, electromagnetic, and weak nuclear forces in terms of a single underlying field. All such theories omit the force of gravity; it has proved difficult to formulate a theory uniting gravity to the other forces. A theory of everything (TOE) did not yet exist as of 2008.

GRANT PROPOSAL: A formal request for a sum of money (a grant) from a private foundation or a government agency. The authors must describe their qualifications, the question their research is designed to address and how it will address it, what results they think will probably be obtained, and what the importance of their proposed work will be. Usually more grant proposals are received than can be funded, so the process of obtaining grants is competitive.

GRAPH: A flat representation of information on a pair of coordinate axes at right angles to each other (i.e., Cartesian coordinates). Each axis represents a variable, and each point on the graph represents a pair of variable values. Marks on the graph make the relationship between the two variables visually apparent. Graphs are the most common method of representing quantitative information visually.

GRAPHIC USER INTERFACE (GUI): (Pronounced "gooey.") Visual computer displays that are responsive to human users. Input to the display from the user may be via touch-screen, graphics tablet, keyboard, mouse, voice command, eye movement, or the like. Software in the computer decides on an appropriate response and changes a graphic display accordingly: For example, in response to a mouse movement, a GUI may move a cursor, shift an icon or image, or show other changes.

GREENHOUSE EFFECT: The warming of Earth's atmosphere due to water vapor, carbon dioxide, and other gases in the atmosphere that trap heat radiated from Earth's surface.

GREENHOUSE GAS: A gaseous component of the atmosphere contributing to the greenhouse effect. Greenhouse gases are transparent to certain wavelengths of the sun's radiant energy, allowing them to penetrate deep into the atmosphere or all the way into Earth's surface. Greenhouse gases and clouds prevent some of infrared radiation from escaping, trapping the heat near Earth's surface where it warms the lower atmosphere. Alteration of this natural barrier of atmospheric gases can raise or lower the mean global temperature of Earth.

GROSS DOMESTIC PRODUCT (GDP): A measure of total economic activity, whether of a nation, group of nations, or the world: slightly different from gross national product (GNP; used by economists until the early 1990s). Defined as the total monetary value of all goods and services produced over a given period of time (usually one year). GDP's limitations have been pointed out by many economists. GDP is a bulk or aggregate statistic and does not take into account inequity: thus, a country's GDP might increase while 99% of its population got poorer, as long as the richest 1% grew sufficiently richer during the same period.

GUILD: In the economy of medieval Europe, an association of craftsmen (e.g., bakers, stonemasons) that controlled admission to the profession, prices, and other aspects of their trade.

GUILLOTINE: An execution device that drops a heavy blade on the neck of the condemned, cutting off the head. Versions of the guillotine were used beginning in the Middle Ages, but the device acquired fame and its present name during the French Revolution, when Joseph-Ignace Guillotin (1738–1814) proposed it as a humane alternative to the usual methods of execution, which often involved torture (e.g., breaking on the wheel, which involved tying a person spread-eagle on a large, spoked wheel and breaking all their bones with a hammer).

H

HADRON: Subatomic particles that are affected by the strong nuclear force; they include both baryons (three-quark particles such as protons, neutrons, etc.) and mesons (two-quark particles such as pions).

HALF-LIFE: The time it takes for half of the original atoms of a radioactive element to be transformed into the daughter product.

HANTAVIRUS: A class of viruses carried by rodents that can infect human beings.

HAPLOID: Having a single set of unpaired chromosomes.

HEAT SHIELD: Any device that protects another, more delicate device from heat. The term is most often used for the lens-shaped caps of special material placed on the leading surfaces of space vehicles designed to enter atmospheres at high speed. During re-entry, compression of air in front of the heat shield heats the air to high temperatures. Some of this heat is absorbed by the heat shield, while some is left behind in a trail of heated air or radiated away. Transforming kinetic energy (energy of motion) to heat energy in this way slows the spacecraft. A heat shield may simply re-radiate the heat it has absorbed (as is done by the ceramic tiles on the space shuttle) or it may also allow some of its material to ablate (vaporize), removing more heat.

HELIOCENTRIC: A heliocentric model of the solar system places the sun at the center of the universe, with the planets and Earth orbiting around it.

HELIOCENTRISM: The theory that the sun lies at the center of the universe (or solar system) and Earth is in motion around it.

HELPER T CELL: (Better known as a T helper cell or effector T cell.) A type of white blood cell that does not directly attack pathogens (invading organisms) but plays a supportive role in triggering and guiding attack by other white blood cells.

HELSINKI DECLARATION: In June 1965, in Helsinki, Finland, the World Medical Association adopted a statement of ethical guidelines for the conduct of research involving human beings. The Helsinki Declaration has since been revised a number of times to reflect advances in ethical understanding. The basic principle is respect for human autonomy, that is, the right to make medical decisions based on an accurate understanding of the situation and free from efforts at coercion or manipulation.

HEMATOLOGY: The medical study of blood (from the Greek *haima*, blood).

HEMOCOEL: Invertebrates (animals lacking a spinal column) do not have a circulatory system of tubular arteries, capillaries, and veins: Instead, they have a body cavity of complex shape, the hemocoel, which contains circulating fluid (including blood) that bathes the creature's organs and muscles, supplying oxygen and removing wastes.

HEMOCYTE: Any blood cell, especially in an invertebrate (animal lacking a spinal column).

HEMOGLOBIN: The protein pigment in red blood cells that transports oxygen to the tissues and carbon dioxide from them.

HEMOLYTIC ANEMIA: A type of anemia caused by destruction of red blood cells at a rate faster than that at which they can be produced.

HERBAL: Herbal remedies or medicines are those derived directly from edible or medicinal plants (herbs) with a minimum of processing: typically, an herbal remedy consists of the dried and possibly crushed or powdered leaves of the plant.

HEREDITY: The genetic link between successive generations of living things.

HERITABILITY: The quality of being able to be passed on from parent to offspring. The more heritable a trait or characteristic is, the more likely it is to be passed on. The random appearance of heritable traits and their sifting by natural selection (which is non-random) is the basis of biological evolution.

HERTZ (HZ): The hertz (Hz) is the unit of frequency, defined as the number of times that an event is repeated in 1 second. It is named after German radio engineer Heinrich Hertz (1857–1894).

HERTZSPRUNG-RUSSELL DIAGRAM: A graphic representation of information about different kinds of stars. It was designed around 1910 by Danish astronomer Ejnar Hertzsprung (1873–1967) and American astronomer Henry Norris Russell (1877–1957). Each star is plotted as a dot on the graph. The horizontal dimension of the graph is in color (whiter stars to the left, redder stars to the right) and the vertical dimension is brightness (brighter stars higher up, dimmer stars lower down). The Hertzsprung-Russell diagram shows that the stars form several distinct patches or groups; these are related to different stages in each star's life cycle and to the mass of the star.

HETEROTOPIC: A heterotopic cell or tissue is one that is growing in an inappropriate location; for example, in the disease known as heterotopic ossification, bone grows in soft body tissues.

HEURISTICS: In artificial intelligence, flexible rules that allow a system to learn.

HIERARCHY OF HUMAN NEEDS: Also known as Maslow's hierarchy of needs, proposed by American

psychologist Abraham Maslow (1908–1970) in 1943. Maslow proposed that human needs can be organized in a hierarchy or pyramid, with people addressing higher-up needs only after satisfying lower-down needs. The levels of need in Maslow's hierarchy, from the bottom up, are physiological (food, sex, air, etc.), safety, love, esteem, and self-actualization (creativity, ethics, etc.). The accuracy of this way of viewing human need and motivation has been disputed by some other psychologists.

HIGGS BOSON: The only particle predicted by the current Standard Model of particle physics that has not yet (as of early 2008) been experimentally observed. The Higgs boson, if it exists, is responsible for endowing all matter with mass. Intense and expensive searches for evidence of the Higgs boson are ongoing at the CERN laboratory in Europe and elsewhere.

HOLE: In the physics of solid materials (solid-state physics), a place in a crystalline array of atoms where an electron is missing, creating a localized positive charge. In semiconductors, holes can travel through the crystal as electrons shift, moving the gap from one position to the next. A moving hole behaves exactly as if it were a positively-charged particle or charge carrier.

HOLISM: A style of thought that can be contrasted to reductionism. Reductionism assumes that the properties of any complex system—a human brain, an ecosystem, or other—can be reduced to the interactions of its component parts (hence "reductionism"). Holism asserts that at least some system properties arise out of the system as a whole (hence "holism") and are not possessed by, or reducible to, the properties of the system's isolated, individual parts.

HOMEOPATHY: An alternative medical system invented by German doctor Christian F.S. Hahnemann (1755–1843) in the early 1800s. In homeopathy, diseases are treated using extremely small doses of substances believed to cause symptoms resembling the disease itself. Some remedies marketed as homeopathic are actually herbal remedies (e.g., arnica gel for its anti-inflammatory properties) and contain significant quantities of their active ingredients; these remedies are not, strictly speaking, homeopathic. Homeopathy is pseudoscientific (i.e., appears scientific but is not): Controlled studies have shown that homeopathy is no better than the placebo effect, which is the tendency of patients to feel better if they believe they are receiving an effective treatment, regardless of the presence of any actual treatment.

HOMEOSTASIS: State of being in balance; the tendency of an organism to maintain constant internal conditions despite large changes in the external environment.

HOMOLOGOUS SERIES: A group of organic compounds that have similar structure and chemical properties.

HOMOLOGOUS STRUCTURE: In evolutionary biology, a homologous structure in an organism is one that resembles a structure in another because both organisms share an ancestor. That is, the similarity is inherited. For example, the leg and finger bones found in humans, whales, bats, and horses are, despite wide differences in shape and use, similar in number and basic pattern: They are homologous structures evolved from the limb bones of the most recent common ancestor of all those species.

HOMOLOGY: Two structures are considered homologous when they are inherited from a common ancestor that possessed the structure. This may be difficult to determine when the structure has been modified through descent.

HOMOPLASY: Similarity between independently evolved structures in two different organisms. For example, the resemblance in outline between a shark and a dolphin is a homoplasy: The two evolved this shape from ancestors that had completely different shapes.

HOPS: Dried flowers of the vine *Humulus lupulus*, which give beer its characteristic bitter flavor and aroma.

HORMONE: A chemical produced in living cells that is carried by the blood to organs and tissues in distant parts of the body, where it regulates various bodily functions.

HOROSCOPE: A forecast, produced by an astrologer, of a person's immediate or long-term future based on the apparent positions of the stars and planets at the time of the person's birth. Such forecasts have no scientific basis.

HOSPITALISM: A nineteenth-century term for the epidemic septic diseases of hospital wards.

HTML: Hypertext markup language (HTML) is a system of instructions that can be used to define the appearance and behavior of a hypertext document. Hypertext is computer-displayed text that not only conveys a direct message, but, if clicked on by a user, acts as a link to other information (e.g., image, sound, text). HTML is the basis of the World Wide Web of linked hypertext documents. The earliest version of HTML was developed by physicist Tim Berners-Lee (1955–) in 1991.

HUMAN GEOGRAPHY: The study of the relationship of human beings to their environment, especially as related to spatial patterns of human settlement (where people live, how densely they settle, how they exploit their environment, etc.).

HUMOR: The ancient Greek and Roman theory of physiology stated that four basic substances, the humors, exist in the human body, and that disease is caused by imbalance among the humors. The four humors were blood, phlegm, yellow bile, and black bile.

HUMORAL THEORY OF DISEASE: The ancient Greek and Roman theory of physiology stated that four basic substances, the humors, exist in the human body, and that disease is caused by imbalance among the humors. The four humors were blood, phlegm, yellow bile, and black bile. The theory proposed that not only disease but temperament or disposition—what psychologists now call personality—were determined by humoral balance.

HURRICANE: Large, rotating system of thunderstorms whose highest wind speed exceeds 74 mph (119 km/h). Globally, such storms are termed tropical cyclones. The word "hurricane" is often reserved for tropical cyclones in the Atlantic.

HYDROCARBON: A chemical containing only carbon and hydrogen. Hydrocarbons are of prime economic importance because they encompass the constituents of the major fossil fuels, petroleum and natural gas, as well as plastics, waxes, and oils. In urban pollution, these components—along with NO_x and sunlight—contribute to the formation of tropospheric ozone.

HYPERFINE RADIO EMISSION: In radio emissions, the presence of very similar emission frequencies (vibration rates of electromagnetic waves emitted by the atom) from a substance such as hydrogen or helium that appear as closely-spaced lines on a spectrum.

HYPERTEXT: Hypertext is computer-displayed text that not only conveys a direct message but, if clicked on by a user, acts as a link to other information, whether text, audio, or image.

HYPOTENUSE: The longest side of a right triangle, which is opposite the right angle.

HYPOTHESIS: An idea phrased in the form of a statement that can be tested by observation and/or experiment.

HYSTERIA: Any state of overexcited or exaggerated emotion. In psychology, the term once referred to a disorder characterized by attention-seeking, extreme emotionalism, and somaticization (conversion of psychological stresses into physical symptoms). For many centuries, hysteria was thought to be a disorder particular to women, hence its name, which comes from the Greek for uterus, *hystera*. In recent decades, psychiatrists have rejected the idea that there is any psychiatric disorder suffered only by women and no longer diagnose "hysteria." The symptoms once associated with hysteria are now associated with other diagnoses, such as somaticization disorder and histrionic personality disorder.

I

IATROCHEMISTRY: A school of European medical-scientific thought that flourished mostly in the 1500s. It was descended from alchemy and was, in some ways, a precursor of modern medical science: Iatrochemists taught that medicines should be based on alchemy (chemistry as it was then understood).

IATROGENIC: (Pronounced eye-at-roh-GEN-ik.) Any infection, injury, or other disease condition caused by medical treatment.

IGNEOUS: Any rock that has formed directly out of molten material, such as lava or granite. Most other rocks are sedimentary, that is, have formed by the accumulation and cementing together of small particles (sediments) deposited by wind or water; or they are metamorphic, that is, have started out sedimentary but then been partially melted before being allowed to resolidify.

IMMUNITY: The condition of being able to resist the effects of a particular disease.

IMMUNIZATION: The process by which resistance to an infectious disease is increased.

IMMUNOGLOBULIN: An immunoglobulin (also known as an antibody) is a large, Y-shaped protein found in blood that combines with a specific substance foreign to the body (antigen). Typical antigens are molecules found on the surfaces of viruses and bacteria. Some immunoglobulins, when bound to antigens, act as flags targeting the antigen for attack by a white blood cell; others combine with other blood molecules to attack the antigen directly. If a person's blood already contains immunoglobulins (antibodies) for a particular antigen, the person's immune system attacks that antigen as soon as it appears: This is the basis of acquired immunity to specific viruses and bacteria, whether natural or instilled by immunization.

IMMUNOLOGY: The study of how the body responds to foreign substances and fights off infection and other disease. Immunologists study the molecules, cells, and organs of the human body that participate in this response.

IMMUNOSUPPRESSIVE: An immunosuppressive drug is one that suppresses or decreases the functioning of the immune system. Such drugs are given with organ transplants in order to prevent the immune system from attacking and destroying (rejecting) the transplanted organ.

IN SILICO: The phrase "in silico" is a pseudo-Latin phrase coined to describe experiments that happen only in the form of computer simulations. "Silico" is a reference to the fact that computers perform calculations using circuits made mostly of silicon. The phrase is based on the phrases "in vivo" (said of experiments performed in a live subject) and "in vitro" (said of experiments performed in a glass container in the laboratory).

***IN VITRO*:** In the laboratory or under laboratory conditions (e.g. in the bacteriological context, the cultivation of organisms in glass Petri dishes).

***IN VIVO*:** In the bacteriological context, growing microorganisms in experimental animals.

INDEPENDENCE: In the mathematical field of probability and statistics, two experiments or observations, say A and B, are independent if the occurrence of a certain outcome for event A does not influence the probabilities for the possible outcomes of event B.

INDUCTION: A form of logical reasoning. In induction, one reasons from particular facts to general laws or principles. For example, by making measurements of how dropped stones accelerate, one might induce the law of gravitation. The complementary form of reasoning is deduction, which reasons from general principles to particular events. For example, knowing that a stone has been dropped at a certain time and place and knowing the law of gravitation, one can deduce when the stone will strike the ground.

INERTIA: A behavior exhibited by moving bodies. Aristotle defined it in the 300s BC as the tendency of moving bodies to come to rest and remain at rest. Galileo redefined it in the AD 1600s as the tendency of moving bodies to remain in motion unless acted on by an outside force.

INERTIAL REFERENCE FRAME: A system of coordinates (spatial measurements of height, length, and width) that is stationary with respect to a point that is moving at constant speed in a straight line. The special theory of relativity, announced by German physicist Albert Einstein (1879–1955) in 1905 and now a basic part of physics, describes the behavior of objects in inertial reference frames.

INFINITY: Infinity is a mathematical quantity greater than any particular number, symbolized by ∞. The concept was first developed in India about 1,600 years ago.

INFORMED CONSENT: An ethical and informational process in which a person learns about a procedure or clinical trial, including potential risks or benefits, before deciding to voluntarily participate in a study or undergo a particular procedure.

INFUSORIA: A group of minute organisms found in decomposing matter and stagnant water.

INOCULATION: Treatment with a vaccine to produce immunity to a disease. Inoculation produces immunity by triggering production of antibodies in the body that attach to virus particles or bacteria that cause the particular disease. If such disease organisms do appear in the body, the antibodies attach to the organisms, and the body attacks them at once, preventing infection.

INORGANIC: Composed of minerals that are not derived from living plants and animals.

INTEGRATE: In mathematics, to perform the act of integration on a function—interpreted geometrically—to find the area under the curve of the function. In electronics, to integrate is to create multiple electronic devices (transistors, capacitors, resistors, etc.) in the substance of a single crystal substrate, such as a chip of silicon. Devices made in this way are termed integrated circuits.

INTEGRATED CIRCUIT: A system of interconnected electronic components such as transistors and capacitors that have been built as part of a single, solid crystalline structure of silicon or some other semiconductor. Because the components are integral to (a continuous part of) a single solid object, they are said to form an integrated circuit.

INTERFERENCE: The interaction of two or more waves.

INTERFEROMETER: Any instrument that uses the phenomenon of optical (light) wave interference to make measurements. Interferometers may be used to make extremely fine measurements of distance between two objects. In astronomy, an array of two

or more telescopes linked electronically so as to record differences between light waves arriving simultaneously at the various telescopes is called an interferometer.

INTERNAL REVIEW BOARD (IRB): Also known as an institutional review board. A committee of personnel in a hospital where research involving human subjects is performed. The IRB's mission is to make sure that such work strictly obeys laws governing research involving humans.

INTERNET: A vast worldwide conglomeration of linked computer networks. The most significant component of the Internet is the World Wide Web.

INTERTIDAL: Between the tides. The intertidal zone is the area of land along the shore that is covered by water when the tide is highest and exposed when it is lowest.

INTUITIONIST: Mathematicians who affirm the intuitionist theory of the meaning of mathematics, which is that a mathematical statement is true if the mathematician can intuit (directly perceive) the truth of that statement.

INVASION ECOLOGY: The study of the ecological consequences of the introduction of invasive species, that is, species that have evolved in different ecosystems.

ION: Removing or adding electrons to an atom creates an ion (a charged object very similar to an atom).

ION ENGINE: A form of reaction engine that propels a spacecraft by ejecting high-speed charged atoms (ions) opposite to the direction of desired acceleration rather than by ejecting a stream of hot gas, as is done by a conventional rocket. Ion propulsion is more energy-efficient than rocket propulsion but produces far smaller thrust and can only be used for slow maneuvers in space, such as orbital adjustment or mid-course correction.

IONIC: In chemistry, an ionic bond between two atoms is formed when the atoms are ionized (given a positive or negative charge by the addition or removal of electrons) and then brought close enough together to be bound by electrical attraction. In architectural history, Ionic or Ionian classic architecture is distinguished by its use of stone columns ornamented by scrollwork at the top.

IONIZING RADIATION: Any electromagnetic or particulate radiation capable of direct or indirect ion production in its passage through matter. In general use, radiation that can cause tissue damage or death.

ISOMERISM: The occurrence of chemical compounds that have the same composition (the same numbers of the same types of atoms) but different geometrical arrangements of those atoms and, as a result, different physical properties. Two substances with the same atomic ingredients but different structure are called isomers.

ISOMERS: Two substances with the same atomic ingredients but different structures. They have the same composition (the same numbers of the same types of atoms) but different geometrical arrangements of those atoms and, as a result, different physical properties.

ISOTACH: (Literally, "same-speed.") A line on a weather map that connect points of equal wind velocity. Crossing from one isotach to another corresponds to movement from a region of higher wind speed to lower, or vice versa.

ISOTHERM: (Literally, "same-heat.") A line on a map or other drawing that connects points of equal temperature. Crossing from one isotherm to another corresponds to movement from a higher temperature to a lower, or vice versa.

ISOTOPE: Two or more forms of the same element with the same number of protons (atomic number), but different numbers of neutrons (atomic mass), e.g. ^{233}U and ^{235}U are two isotopes of uranium; both have 92 protons, but ^{233}U has 141 neutrons and ^{235}U has 143 neutrons.

J

JET STREAM: Currents of high-speed air in the atmosphere. Jet streams form along the boundaries of global air masses where there is a significant difference in atmospheric temperature. The jet streams may be several hundred miles across and 1–2 miles (1.6–3.2 km) deep at an altitude of 8–12 miles (12.9–19.3 km). They generally move west to east and are strongest in the winter, with core wind speeds as high as 250 mph (402.4 km/h). Changes in the jet stream indicate changes in the motion of the atmosphere and weather.

JOULE (J), KILOJOULE (KJ): The joule (J) is the unit of work in physics and engineering. It is named after English physicist James Prescott Joule (1818–1889) and is defined as the work done by a force of 1 newton (N) moving through a distance of 1 meter (m): $1\ J = 1\ N \times m = 1\ kg\ ṡm^2/s^2$.

JOURNEYMAN: In the European economy in the Middle Ages, a person who had completed their

apprenticeship (learned the essentials of their specific trade) but had not yet achieved the status of a master craftsmen. Journeymen often traveled from job to job or worked briefly for various employers.

JUNCTION TRANSISTOR: A transistor is an electronic device that controls a current flow in response to a separate electrical signal, like a valve regulating the flow of water through a faucet. A junction transistor, also known as a sandwich transistor, consists of three pieces or regions of semiconducting crystal arranged in a sandwich. The outer layers consist of crystal that has been doped (slightly contaminated with atoms that donate electrons, endowing the crystal with negative charges); the middle layer consists of crystal that has been doped with atoms that lack electrons, endowing the crystal with positive charges. (A sandwich can also be made with positive and negative in reversed roles.) The ability of the junction transistor arises from the properties of the junctions between the positively and negatively doped silicon, hence the name.

K

KAMAL: An observational instrument used in the Middle East and China from the Middle Ages through the nineteenth century. Like the cross staff, its purpose was to allow measurement of the angle between a particular astronomical object (usually a star) and the horizon. A wooden card attached to a string is held at arm's length while the string is held in one's teeth: one then moves the card along the string until it is aligned with the star. Knots along the string are then counted to the position of the card, providing a reading for the angle.

KAON: Also known as a K-meson. A fundamental particle containing a single quark. It is a type of meson and is several times heavier than a pion.

KINETIC ENERGY: The energy due to the motion of an object.

KOCH'S POSTULATES: In 1884, German doctor Robert Koch (1843–1910) and scientist Freidrich Loeffler (1852–1915) announced a set of standards—later refined by Koch—that they said would have to be met before an organism could be declared the cause of a given infectious disease. First, the germ must be found in all diseased organisms but not in healthy ones; second, the germ must be capable of being isolated and grown in culture; third, a healthy organism inoculated with the germ must contract the disease; and fourth, the inoculated organism must supply germs that are identical with those isolated originally from diseased organisms. Koch's postulates are now known to be too strict; not all disease-causing organisms can be grown in culture, for example, and not all organisms colonized by a disease-causing organism necessarily become sick.

KREBS CYCLE: A set of biochemical reactions that occur in the mitochondria. It is the final common pathway for the oxidation of food molecules such as sugars and fatty acids. It is also the source of intermediates in biosynthetic pathways, providing carbon skeletons for the synthesis of amino acids, nucleotides, and other key molecules in the cell. The Krebs cycle is also known as the citric acid cycle and the tricarboxylic acid cycle. The Krebs cycle is a cycle because, during its course, it regenerates one of its key reactants.

K-T BOUNDARY: At the very end of the Cretaceous period and the beginning of the Tertiary period, 65.5 million years ago, a mass extinction wiped out 65–70% of all plant and animal species in a short time. The layer or boundary separating Cretaceous sediments from Tertiary sediments is termed the K-T boundary. This layer is rich in iridium, an element more common in meteorites than Earth rocks, which suggests that the extinction was caused by an asteroid striking Earth. The Chicxulub crater in the Yucatan Peninsula, Mexico, was probably caused by this impact.

L

LABILE: Easily changed or highly variable; the term is especially used in psychology, where it describes emotional states that are especially prone to change. For example, a person who is smiling one moment, crying the next, and smiling again soon after is displaying labile emotions.

LACTOBACCILLUS: A type of anaerobic (non-oxygen-using) bacterium that is found in the human gut and in nature and is also used in preparation of fermented foods such as yogurt, kimchee, and sauerkraut.

LAMARCKISM: The belief that acquired characteristics can be inherited, that is, that changes to an organism that happen during its life can be passed on to offspring.

LAMBDA: Lambda (λ or Λ) is the eleventh letter of the Greek alphabet. It is used throughout the physical sciences to denote certain objects or classes

of objects: for example, in cosmology it denotes the cosmological constant; in biology it is a type of bacterium used in genetic research (lambda phage), etc.

LANDSCAPE: An area of land having a definite local character that includes any structures or changes created by human beings. Generally, a landscape supports a single ecosystem or part of one. The term has no strict definition in geography or biology.

LASER: Acronym for light amplification by stimulated emission of radiation; a device that uses the movement of atoms and molecules to produce intense light with a precisely defined wavelength.

LASER MEDIUM (ACTIVE MEDIUM): Also known as an active medium or gain medium. The physical substance—liquid, solid, or gas—inside a laser that produces optical gain (amplification) by converting energy from an outside source into coherent laser light.

LATENT ENERGY: Also called latent internal energy or latent heat. The latent energy of a physical system is energy stored in the system by virtue of its phase (liquid, solid, or gas). For example, water contains latent energy that is released during freezing (i.e., freezing water releases latent energy as heat).

LATITUDE: The angular distance north or south of Earth's equator measured in degrees.

LAW OF LARGE NUMBERS: In the mathematics of probability, the statement that a large number of random experiments of the same type will, over many trials, produce outcomes that average out to the expected value, that is, the value predicted for the random variable describing those experiments. For example, the number of times that heads appears when flipping a fair coin is described by a random variable with an expected value of 50%, i.e., heads and tails are equally likely to appear. For a small number of flips, heads may not appear on 50% of flips: indeed, for three flips, the closest heads can possibly appear to half is 1 out of 3 (33%) or 2 out of 3 (66%) of the time. But if many flips—hundreds or thousands—are tried, the percentage of heads will inevitably converge to 50%, as predicted by the law of large numbers.

LAW OF SUPERPOSITION: In geology, the law of superposition states that barring the overturning of rock layers by later processes, deeper layers are always older than shallower layers. The law holds because (apart from later disruptions) sediments laid down earlier must be on the bottom and later materials must be on the top, like ingredients being added to an open-faced sandwich.

LENS: A lens is any substance that transmits or refracts light. Gravity can act as a lens and bend light near very massive objects such as stars. Water can act as a lens to refract (bend) light. In common use (such as the lens found in eyeglasses), a lens is often made of glass or similar substance to specifically bend the path of light so as to either focus it on a certain point or cause it to diverge away from it's established path. A simple lens has one refracting element or body. A compound lens is an array of multiple lenses. A lens may also act to refract light in portions of the electromagnetic spectrum outside that of visible light (e.g., radio lens, microwave lens, ultraviolet lens, etc.) Also, an almost clear, biconvex structure in the eye that, along with the cornea, helps to focus light onto the retina. It can become infected with inflammation, for instance, when contact lenses are improperly used.

LEPTONS: A group of subatomic particles not composed of quarks that includes electrons, muons, and tau particles.

LIBRARY: A collection of documents or records, whether printed, digitized, or stored in any other medium. In modern usage, the ability to access information stored outside the library, such as on distant computers accessed through the Internet, is part of the definition of a library. In computer science, a library is a collection of related software entities accessed by one or more programs (e.g., a font library accessed by word processing programs and graphics programs).

LICENSE: An official government permission to carry on a certain activity. While science is not a licensed profession, medicine is. To practice as a doctor in the United States, one must possess a license granted by the state in which one has attended medical school. In most other countries, medical licensure is granted by the central government.

LIFESTYLE DRUG: Any medication that is used to treat a non-medical condition such as wrinkles or baldness. The term is sometimes applied to medications for non-life-threatening conditions such as impotence.

LIGATION: The surgical tying-off or pinching of a tube in the body so that it is closed. Ligation is used in surgery to prevent blood loss from major vessels; ligation of the fallopian tubes, termed tubal ligation, is a method of sterilizing women and other female mammals.

LIGHT YEAR: Despite its name, the light year is a unit of distance, not time. The distance traveled by light in a vacuum in a period of one year, equal to 5.878 trillion miles (9.4607×10^{12} km). The nearest

star to our own sun, Proxima Centauri, is a little over four light years away.

LIMNOLOGY: The scientific study of lakes, ponds, and other freshwater bodies.

LINCEI: (Italian for "lynx") The short name for Accademia dei Lincei, a science academy in Italy that was founded in 1603 by Italian botanist Federico Cesi (1586–1630).

LIPID: A fat or oil; a chemical compound used as a source of enérgy, to provide insulation, and to protect organs in an animal body.

LIPOPROTEIN: A large molecule composed of a lipid, such as cholesterol, and a protein.

LITHOTOMY: (From the Greek *lithos*, stone.) Any surgical operation to remove a stonelike object from the body, such as a gallstone or stone in the bladder.

LITTLE ICE AGE: A cold period that lasted from about AD 1550 to about AD 1850 in Europe, North America, and Asia. This period was marked by rapid expansion of mountain glaciers, especially in the Alps, Norway, Ireland, and Alaska. There were three maxima, beginning about 1650, about 1770, and 1850, each separated by slight warming intervals.

LOBOTOMY: Also termed psychosurgery. An operation in which damage is deliberately caused to the prefrontal cortex of the brain, a part of the brain associated with conscious behavior, socializing, and complex intellectual activity. The purpose of the operation is to produce a more passive personality in persons either mentally ill or supposed by others to be mentally ill, however, its effects can include destruction of the personality. The operation was particularly popular in the United States from the 1930s through the 1970s. Today, lobotomy is often viewed as a violation of human integrity; in 1996, Norway announced that it was paying compensation to all living lobotomy victims.

LOGISTIC MAP: An equation that describes the growth or shrinkage of a hypothetical population of organisms. It is noted for its chaotic long-term behavior: That is, very slight differences in initial conditions lead to widely different populations at future times.

LONGITUDE: The angular distance from the Greenwich meridian (0 degree), along the equator. This can be measured either east or west to the 180th meridian (180 degrees) or 0 degree to 360 degrees W.

LORAN CHART: The Long Range Navigation (LORAN) system was set up after World War II (1939–1945) to aid ocean surface navigation. Radio pulses from fixed stations are compared by LORAN receivers on board ships; the time differences between receipt of pulses from different stations can be used to calculate position. LORAN charts are maps that show where different pulse-timing differences will be observed on the surface, drawn as colored lines on the map.

LUMINOSITY: The amount of light given off by an object. In astronomy, brightness is the amount of light from a star as seen on Earth, while luminosity is the amount of light actually given off by the star. Closer stars look brighter even though they may or may not be more luminous. Luminosity is measured in units of absolute magnitude, given by a mathematical formula stating how bright a given star would look if located at a standard distance from Earth.

LYCEUM: The garden in Athens where Greek scientist and philosopher Aristotle (384–322 BC) taught his students.

LYMPH: A fluid that runs through the lymphatic vessels, lymph nodes, and other lymphatic organs.

LYMPHOCYTE: A type of white blood cell that functions as part of the lymphatic and immune systems by stimulating antibody formation to attack specific invading substances.

LYSENKOISM: A type of pseudoscience, named after its founder, Trofim Lysenko (1898–1976), that arose in the Soviet Union in the 1930s and destroyed Soviet biology for decades. Lysenkoists denounced modern evolutionary biology and genetics.

LYSOZYME: An enzyme, discovered by Alexander Fleming (1881–1955), that kills bacteria.

M

MAGELLANIC CLOUDS: Small, irregularly-shaped galaxies near our own galaxy, the Milky Way, visible in the night sky of the Southern Hemisphere. They are named after Portuguese explorer Ferdinand Magellan (1480–1521), who was the first European to note them.

MAGNETIC FIELD: The space around an electric current or a magnet in which a magnetic force can be observed. Stationary magnets or moving electric charges will experience a magnetic force—a physical push or pull—inside a magnetic field.

MAGNETIC RESONANCE IMAGING (MRI): A form of medical imaging developed in the 1970s. In MRI,

the body is placed in a strong magnetic field that aligns the nuclei of the body's atoms. The nuclei are then struck with brief pulses of radio-frequency electromagnetic radiation. Radio energy re-radiated from the nuclei is recorded by detectors around the body and processed by a computer to yield a cross-sectional image or, in some devices, a three-dimensional image.

MAIN SEQUENCE: A range of star types that includes most stars. It appears as a wavy diagonal stripe on the Hertzsprung-Russell diagram, a color-versus-brightness graph on which each star is represented as a dot. Typically, a newly formed star appears on the main sequence, remains there until it has exhausted its original nuclear fuel, then migrates off the main sequence to become a red giant. Eventually it migrates again to become a white dwarf (also off the main sequence).

MAJOR HISTOCOMPATIBILITY COMPLEX (MHC): The proteins that protrude from the surface of a cell that identify the cell as "self." In humans, the proteins coded by the genes of the major histocompatibility complex (MHC) include human leukocyte antigens (HLA), as well as other proteins. HLA proteins are present on the surface of most of the body's cells and are important in helping the immune system distinguish "self" from "non-self" molecules, cells, and other objects.

MALIGNANT: Cancerous.

MARICULTURE: The raising of plants or animals in seawater, usually for food, whether in the actual ocean or in an enclosure of some kind. Kelp, shrimp, and pearl oysters are examples of maricultured species.

MARINE: Refers to the ocean.

MARINER: A sailor. Also, Mariner refers to any of a series of ten robotic spacecraft launched by the United States from 1962 to 1973. The Mariners visited Venus, Mars, and Mercury.

MARSUPIALS: A subclass of mammals. All marsupials bear their young at an early, almost embryonic, stage of development and then care for them inside a skin pouch called the marsupia. Opossums and kangaroos are typical marsupials.

MASS: Measure of the total amount of matter in an object. Also, an object's quantity of matter as shown by its gravitational pull on another object.

MASS EXTINCTION: A type of extinction event characterized by high levels (or rates) of species extinction in a geologically short period of time.

MASTER: In computer science and electrical engineering, a device that controls another device is sometimes termed a master. In this case, a device controlled by the master is termed a slave.

MATERIAL THEORY OF HEAT: Several material theories of heat were proposed in previous centuries. According to these theories of heat, heat is a material substance or fluid; when one body is heated and another cooled, this fluid is supposed to flow from the hot to the cool body. Since the nineteenth century it has been known that heat is actually the rapid, random motion of atoms and molecules, not a substance in its own right.

MATRILINEAL: Refers to descent through the mother. This descent may be cultural—for example, Jewishness is often defined as descent from a Jewish mother—or biological, as in the case of mitochrondrial DNA. Mitochondria are organelles found inside cells that have separate DNA from the rest of the cell; their DNA is descended from the egg cell supplied by the mother, since sperm contain far fewer mitochrondria and the few mitochondria they do contain do not enter the egg during fertilization.

MATRIX (PLURAL: MATRICES): In mathematics, a matrix is an array of numbers, variables, or equations arranged in rows and columns. A matrix is often a two-dimensional rectangular array like a chessboard, but matrices may also have more dimensions.

MATRIX MECHANICS: A form of quantum mechanics that provides a mathematical description of the physical laws governing the behavior of atomic- and subatomic-size objects. It was proposed in 1925 by German physicists Max Born (1882–1970), Werner Heisenberg (1901–1976), and Pascual Jordan (1902–1980).

MATTER: Anything that has mass and takes up space.

MAUNDER MINIMUM: A historic dip in the number of sunspots from about 1645 to 1715. During this period the European climate was unusually cold, but this may have been a coincidence. The Maunder minimum is named after English astronomer Edward Maunder (1851–1928), who identified its occurrence from historical records in 1893.

MAXWELL'S EQUATIONS: In 1861, Scottish physicist James Clerk Maxwell (1831–1879) published a set of equations describing the interactions of the electric and magnetic fields. These equations later came to be known as Maxwell's equations and are still basic to physics and engineering.

MEAN FREE PATH: The mean free path of a free-moving particle is the average distance it travels before striking an obstacle (e.g., another particle). The mean free path is longer in less-dense media such as diffuse gases.

MECHANICAL EQUIVALENT OF HEAT: The amount of work that must be done to produce a certain amount of heat. Mechanical work can be converted into heat by friction. Heat and mechanical work (force acting through distance) are interchangeable because heat consists of objects (particles) in motion and thus is essentially mechanical.

MECHANICAL PHILOSOPHY: Mechanical philosophy was a school of thought that prospered in the 1600s and asserted that the universe consists entirely of atoms in motion obeying mechanical laws (where the term "mechanical" refers to the motions and interactions of solid objects, not necessarily to the behavior of artificial machines).

MECHANICAL THEORY OF HEAT: Developed in the mid-nineteenth century and refined since, the theory (system of explanations) stating that heat is not a substance or fluid in its own right but consists entirely of mechanical motions, namely, the motions of particles. In a solid, these motions consist of oscillations or vibrations around a fixed point; in a gas or liquid, they consist of rapid straight-line movement interrupted frequently by collisions with other particles.

MEIOSIS: Process of cell division by which a diploid cell produces four haploid cells.

MENHIR: A large standing stone put in place by human beings, usually in the distant past. Menhirs had religious significance for their makers; often this religious meaning was combined with astronomical properties, such as alignment with the sun or moon at a solstice or other special time.

MESON: Subatomic particles composed of a quark and an antiquark; they participate in strong force interactions.

MESSENGER RNA (mRNA): A long, chainlike molecule that carries information in the cell (hence "messenger" RNA). mRNA is manufactured in the nucleus of the cell, where the chemical code of a section of DNA is copied to an mRNA molecule. This molecule is then transported out of the cell to one of the cell's ribosomes. A ribosome is a molecular factory that uses mRNA as a blueprint for making proteins. Once the mRNA has been used by the ribosome to make a protein, it is broken down by other chemicals in the cell.

METABOLISM: The sum of all the physiological (physical and chemical) processes that take place in a living organism by which the organism maintains life, including the breakdown of substances to provide energy for the organism.

METAMORPHIC: In geology, a sedimentary rock that has been partially melted and then allowed to resolidify. This changes (metamorphoses) the character of the original rock.

METAPHYSICS: The branch of philosophy that is concerned with basic concepts such as time, space, being, reality, and the like. Especially in the twentieth century it has interacted closely with physics, which is also concerned with such questions.

METASTASIS: Spreading of a cancerous growth by shedding cells that grow in other locations.

METEOROLOGY: The science that deals with Earth's atmosphere and its phenomena and with weather and weather forecasting.

METRIC SYSTEM: A system of measurement used by all scientists and in common practice by almost every nation of the world except a few countries, such as the United States.

MICROAEROPHILIC: A type of bacteria that requires oxygen to live, but in relatively small amounts (less than 20% of the concentration found in the atmosphere). Several disease-causing organisms, such as the bacteria that cause Lyme disease, are microaerophilic.

MICROBE: Any microorganism.

MICROBIOLOGY: Branch of biology dealing with microscopic forms of life.

MICROFILM: Microfilms are miniature films used for photographing objects and documents. The images on these films cannot be seen without an optical aid, either in a form of a magnifying glass or a projector.

MICROORGANISMS: All fully-grown, independent living things too small to be seen with the naked eye. Individual cells in the tissues of multicellular organisms are not considered microorganisms, because they are not independent organisms.

MICROWAVE: Electromagnetic radiation with wavelengths between about .039 inches (1 mm) and 3.3 feet (1 m).

MILKY WAY: The galaxy in which our solar system is located.

MITOCHONDRIA: Cellular organelles, of round and elongated shapes, that are found in the cytoplasm and

produce adenosine triphosphate (ATP) near intra-cellular sites where energy is needed. Shape, amount, and intra-cellular position of mitochondria are not fixed, and their movements inside cells are influenced by the cytoskeleton, usually being in close relationship with the energetic demands of each cell type. For instance, cells that have a high consumption of energy, such as muscular, neural, retinal, and gonadic cells present much greater amounts of mitochondria than those with a lower energetic demand, such as fibroblasts and lymphocytes. Their position in cells also varies, with larger concentrations of mitochondria near the intra-cellular areas of higher energy consumption.

MITOSIS: Process of cell division resulting in the formation of two daughter cells genetically identical to the parent cell.

MODERNISM: A style of thought, closely associated with art, literature, and architecture, that arose and flourished in the late nineteenth and early twentieth centuries. Modernists tended to assume that ongoing improvement of the human condition ("progress") was possible through logical thought, applied science, and the construction of rational, unornamented buildings.

MOLECULE: Two or more atoms chemically combined.

MOMENTUM: The mass of a moving object multiplied by its velocity.

MONISM: Any philosophy that denies the existence of duality or division in some aspect of being, such as between mind and body or nature and God. The term can refer to a philosophy or theology that denies the reality of all distinctions whatever.

MONOCHROMATIC LIGHT: Light can be treated, in many circumstances, as a wave traveling through space. Although the velocity of this wave is always the same in a given medium, its rate of vibration can vary. Light waves with rates of vibration (frequencies) in a certain range are visible to the naked eye and so are called visible light. In the visible range, we perceive different frequencies as distinct unmixed colors. Light of a single frequency, unmixed with other frequencies, is therefore termed monochromatic (single-colored) light.

MONOGENY: Monogeny, also called monogenesis, is a theory derived from literal readings of the biblical book of Genesis, which states that all human beings descended from a single original couple (e.g., Adam and Eve). Monogenesis is no longer a scientific theory. It is now known that human beings evolved as a population from populations of pre-human creatures. We do not descend from a literal First Couple and our genetic characteristics show that we have never experienced a population bottleneck as small as a single breeding pair.

MONOPHYLETIC: Term applied to a group of organisms that includes the most recent common ancestor of all of its members and all of the descendants of that most recent common ancestor. A monophyletic group is called a clade.

MOORE'S LAW: For about 40 years, the number of electronic components that can be manufactured on a single integrated circuit (microchip) at a certain cost has doubled every few years. This trend has been described as Moore's law since 1965, when it was identified by U.S. engineer Gordon Moore (1929–).

MORPHOGENESIS: In geology, the development of distinct landforms. In biology, it is an aspect of developmental biology, that is, the biology of the growth of the individual organism. Specifically, it is the development in the growing individual of formed organs and limbs, as distinct from the replication of individual cells or the differentiation of cells into various tissue types (nerve, muscle, epithelium, etc.).

MOTIVE POWER: The motive power of a device is the source of energy that makes it go. The term is usually applied to machines that actually move (e.g., vehicles).

MRI: MRI stands for magnetic resonance imaging, a form of medical imaging developed in the 1970s. In MRI, the body is placed in a strong magnetic field that aligns the nuclei of the body's atoms. The nuclei are then struck with brief pulses of radio-frequency electromagnetic radiation. Radio energy re-radiated from the nuclei is recorded by detectors around the body and processed by a computer to yield a cross-sectional image or, in some devices, a three-dimensional image.

MULSUM: A mixture of honey and wine served as an appetizer at formal meals in ancient Rome.

MULTIVARIATE ANALYSIS: In the mathematics of probability and statistics, multivariate (many-variable) analysis is the mathematical characterization of data using more than one random variable.

MULTIVERSE: Some physicists and cosmologists propose that the universe we observe is only one of an infinite number of universes, either superimposed in this space (in the case of the quantum multiverse)

or, in other theories, located at distances so extreme that they cannot be observed. It is possible that both types of multiverse exist. Multiverse theories are suggested by the equations of physics, but not, so far, by observation. Direct observation of multiverses will presumably never be possible, but indirect evidence for or against their existence may someday be available.

MUST: Grape juice that is going to be fermented to make wine, or is in the process of being fermented.

MYCOLOGY: The branch of biology dealing with fungi.

MYOPIA: A synonym for near-sightedness. It is caused by elongation of the eyeball in the direction of vision so that images of far-away objects are focused inside the eye rather than on the retina (the light-sensitive surface at the back of the eye's interior).

MYXEDEMA: Underactivity of the thyroid gland causes a number of symptoms, including fluid swelling (edema) of the tissues under the skin. This imparts a waxy, smooth appearance to the skin. Either this swelling or the whole complex of thyroid insufficiency symptoms, including weight gain and mental retardation, can be termed myxedema. An obsolete (now offensive) term for the symptoms of congenital thyroid insufficiency is cretinism.

N

NANOTECHNOLOGY: Nanotechnology describes device components that are generally less than 100 nanometers (1/1,000,000 of a millimeter), thus making them on a molecular scale.

NANOTUBE: In materials science, a tube-shaped structure that is molecular in size. Such tubes rarely occur in nature but can be produced in large quantities in the laboratory and are increasingly being put to technological use. Carbon nanotubes, in particular, have useful electrical, optical, and mechanical properties, being extremely strong by weight and excellent conductors of electricity.

NATURAL PHILOSOPHY: A term first used in the late 1300s, "natural philosophy" signifies the study of natural objects and forces—what today is more likely to be termed physical science or physics.

NATURAL SELECTION: Also known as survival of the fittest; the natural process by which those organisms best adapted to their environment survive and pass their traits to offspring.

NATURALISM: Philosophical naturalism is the doctrine that nature is all that exists: There are no souls, spirits, or gods. Methodological naturalism is the practice of looking only for natural (physical) explanations for observable phenomena, while excluding the possibility that spirits, God, gods, or the like have caused phenomena. Methodological naturalism is basic to modern science, but does not require adherence to philosophical naturalism; that is, religious believers may, as scientists, be methodological naturalists without being philosophical naturalists.

NEBULA (PLURAL: NEBULAE): A patch of the night sky that appears cloudy to the naked eye.

NEBULAR THEORY: First proposed by Swedish scientist Emanuel Swedenborg (1688–1772) in 1734, the idea that the sun and its planets formed by condensation of matter from a cloud of dust or gas (a nebula). In more complex form, this remains the scientific explanation for the formation of all planetary systems.

NEUROLOGY: The scientific study of the nervous system, especially its structure, functions, and abnormalities.

NEURON: The basic cellular unit of the nervous system. The unique morphological and intercellular structure of the neuron is dedicated to the efficient and rapid transmission of neural signals. Within the neuron, the neural signal travels electrically. At the synapse, the gap between neurons, neural signals are conveyed chemically by a limited number of chemicals termed neurotransmitters. Specialized parts of the neuron facilitate the production, release, binding, and uptake of these neurotransmitters.

NEUROSURGERY: Any surgery involving the nervous system, but the term usually refers to surgery involving the brain or spinal cord.

NEUROTRANSMITTER: A chemical that transmits electrical impulses (information) between nerve cells or nerve and muscle cells.

NEUTRINO: A high-energy subatomic particle resulting from certain nuclear reactions that has no electrical charge and no mass, or such a small mass as to be undetectable.

NEUTRON: A subatomic particle with a mass of about one atomic mass unit and no electrical charge that is found in the nucleus of an atom.

NEUTRON STAR: An extremely dense object that remains after a massive star explodes in a supernova. Neutron stars have radii of about 6.2 miles (10 km) and masses of about 1.4 to 3.0 solar masses.

(O_2) that occurred about half a billion years ago, just before the diversification of multicellular life known as the Cambrian explosion. Only green plants (e.g., algae) produce O_2 in large quantities. O_2 combines readily with many other molecules and compounds and so does not last long in nature unless continually resupplied. Algae had been producing O_2 for over a billion years by the time of the oxygen crisis, but this oxygen had been absorbed by rocks. When the rocks could no longer absorb O_2 as fast as the algae produced it, the amount of O_2 in Earth's atmosphere increased dramatically.

OZONE LAYER: A layer of ozone that begins approximately 9.32 miles (15 km) above Earth and thins to an almost negligible amount at about 31.07 miles (50 km); it shields Earth from harmful ultraviolet radiation from the sun. The highest natural concentration of ozone (approximately 10 parts per million by volume) occurs in the stratosphere at approximately 15.53 miles (25 km) above Earth. The stratospheric ozone concentration changes throughout the year as stratospheric circulation changes with the seasons. Natural events such as volcanoes and solar flares can produce changes in ozone concentration, but man-made changes are of the greatest concern.

P

PANDEMIC: An outbreak of a disease affecting large numbers of people over a wide geographical area.

PARALLAX: The difference in direction or change of position of an object in the sky when it is viewed from two different points on Earth.

PARAPHYLETIC: Term applied to a group of organisms that includes the most recent common ancestor of all of its members, but not all of the descendants of that most recent common ancestor.

PARASITE: An organism that lives in or on a host organism and that gets its nourishment from that host.

PARTHENOGENESIS: The reproduction from an ovum (egg cell, in animals) without a sperm cell. In parthenogenesis, no male is necessary for reproduction. Many plants and a number of animals are capable of parthenogenesis.

PARTICLE ACCELERATOR: A device for accelerating subatomic particles to very high speeds for the purpose of studying the properties of matter at very high energies.

PATHOGEN: A disease-causing agent, such as a bacteria, virus, fungus, etc.

PATRILINEAL: Descent through the father. This descent may be cultural—for example, in Western culture, family names are usually inherited patrilineally—or biological, as in the case of genes carried on the Y chromosome (which male offspring derive only from the father).

PAULI EXCLUSION PRINCIPLE: In physics, the rule that no two fermions can have the same quantum number, first stated by Austrian physicist Wolfgang Pauli (1900–1958) in 1925. The exclusion principle accounts for the solidity of ordinary matter and the electron-shell structures of atoms, which in turn determine their chemical properties.

PELAGIC: Referring to the open oceans.

PENICILLIN: The first antibiotic, discovered by Sir Alexander Fleming (1881–1955), which is produced by a species of a mold microorganism.

PERIOD: The time it takes for a cyclical phenomenon to repeat. In pulsars, the time between two consecutive pulses.

PERIODIC LAW: Russian chemist Dmitri Mendeleyev (1834–1907) thought there to be a law of nature that would explain why there were regular repetitions of chemical properties when elements were arranged in order of atomic weight.

PERIODIC POTENTIAL: Periodic potential refers to the regular pattern of electric field potential inside a crystal, in which atoms are built up in recurring (periodic) structures like a grid or lattice.

PERMIAN-TRIASSIC EXTINCTION: Some 254.1 million years ago, at the end of the Permian period and the beginning of the Triassic period, the most severe mass extinction on Earth so far occurred. About 95% of all marine species and about 70% of all land-dwelling species disappeared. Various causes have been proposed. Some scientists theorize that several causes, coincidentally occurring near each other in time, caused the extinction.

PERTURBATIONS: In celestial mechanics, deviations of a planet's orbit from the shape predicted for it by Newton's laws.

PET: PET stands for positron emission tomography, a medical imaging technique developed in the 1970s. In PET, a chemical compound is prepared containing atoms of an unstable isotope of carbon, oxygen, nitrogen, or fluorine that emits a positron (antiparticle

of an electron) when it decays. This chemical is designed to be absorbed by target tissues in the body. As the unstable atoms in the tissues decay, the positrons they emit encounter nearby electrons. These electron-positron pairs annihilate, as particle-antiparticle pairs always do when united, emitting two high-energy photons that leave the body in opposite directions. These photons are recorded by detectors surrounding the patient, and this information is processed by a computer to yield three-dimensional images of where radioactivity is occurring in the body. This images the tissues that have absorbed the chemical containing the unstable isotope. PET imaging is particularly used in cancer imaging and brain studies.

PEUTINGER TABLE: Also called the Tabula Peutingeriana, the Peutinger Table is a map copied in the 1200s from an original drawn in the 300s or 400s. The Peutinger Table is the only surviving ancient map showing the Roman system of public roads in Europe, northern Africa, and southern and eastern Asia. It is named not after the original artist, who is unknown, but after a sixteenth-century owner of the document, German politician Konrad Peutinger (1465–1547).

PHAGOCYTES: Phagocytes, also called white blood cells, are cells that circulate in the blood and can engulf and destroy disease organisms such as viruses and bacteria by dousing them with digestive enzymes.

PHASE: In the study of waves, a repeating or periodic wave's phase is the relationship of its pattern of peaks and valleys to a fixed reference (e.g. time).

PHASE TRANSITION: A substance that moves from one physical phase to another—gas to solid or liquid, solid to liquid or gas, liquid to solid or gas—is said to undergo a phase transition.

PHENETICS: In biology, the practice of grouping organisms based on numerical analysis of differences and similarities of anatomy (morphology); it is also termed numerical taxonomy and is an alternative to the more common method, cladistics.

PHENOTYPE: The visible characteristics or physical shape produced by a living thing's genotype.

PHILOSOPHER'S STONE: A material thought by alchemists to have the power to bring about the transmutation of metals.

PHILOSOPHICAL ELEMENTS OR PRINCIPLES: The underlying essential constituents of bodies that cannot be directly perceived.

PHLEBOTOMY: Phlebotomy, also known as bloodletting, is the deliberate medical release of blood from the body, whether by allowing leeches to feed on the patient or by cutting a blood vessel. This technique, which was practiced on a wide variety of patients in Western medicine from Greco-Roman times to the nineteenth century, was rarely of benefit and no doubt did far more harm than good. However, there are certain rare medical conditions, such as hemochromatosis, in which the patient has excessive red blood cells and must undergo regular therapeutic phlebotomy.

PHLEGM: The ancient Greek and Roman theory of physiology stated that four basic substances, the humors, exist in the human body, and that disease is caused by an imbalance among the humors. The four humors were blood, phlegm, yellow bile, and black bile; an excess of phlegm was believed to cause dull-wittedness and apathy.

PHOTOELECTRIC EFFECT: The phenomenon in which light falling upon certain metals stimulates the emission of electrons and changes light into electricity.

PHOTON: Smallest individual unit of electromagnetic radiation (light energy). These light particles are emitted by an atom as excess energy when that atom returns from an excited state (high energy) to its normal state. According to modern physics, it is not accurate to imagine any subatomic particle, including a photon, as a tiny, hard ball: Rather, a particle also has wave properties and is spread out through space. Thus, light has wave properties, despite being conveyed by photons.

PHYLOGENY: The evolutionary relationships among organisms; the patterns of lineage branching produced by the true evolutionary history of the organisms being considered.

PHYSICAL GEOGRAPHY: The subdiscipline of geography that concentrates on natural patterns and features of Earth's (or any other planet or moon's) surface, as opposed to patterns and features produced by human activity.

PHYSIOGNOMY: The pseudoscience of judging character from facial features or expressions, practiced from ancient Greek times through the nineteenth century. Physiognomists supposed that inborn vices or virtues could be detected in such features as closely-set eyes, low or high foreheads, bumps on the skull, and the like. Such beliefs were often recorded in literary descriptions of character, especially in nineteenth century writers.

PHYTOPLANKTON: Microscopic marine organisms (mostly algae and diatoms) that are responsible for most of the photosynthetic activity in the oceans.

PION: A pion or pi meson is a type of fundamental particle containing two quarks. There are three pions; all are involved in carrying the strong nuclear force.

PLACEBO: A false treatment that gives a patient the sense that a medicine is working when, in actuality, no medicine was actually received.

PLANCK'S CONSTANT: A fixed number (constant) that appears in quantum physics. Any photon can only carry some integer multiple (i.e., once, twice, three times, N times) of the fixed energy unit or quantum $E = h\nu$, where E is energy, ν is frequency, and h is Planck's constant, whose value is approximately 6.626×10^{-34} Jśs. German physicist Max Planck (1858–1947) described the value of this constant in 1899 and in 1918 was awarded the Nobel Prize in physics.

PLANETARY ASPECTS: Also called astrological aspects or simply aspects, these are angles measured between planets, as seen from Earth, at a given moment. In astrology, these angles are imagined to be of importance in predicting the planetary influence on a human being's character and fate.

PLANKTON: Floating minute animal and plant life.

PLASMA: Matter in the form of electrically charged atomic particles that form when a gas becomes so hot that electrons break away from the atoms. Also, the colorless, liquid portion of the blood in which blood cells and other substances are suspended.

PLATE: Rigid parts of Earth's crust and part of Earth's upper mantle that move and adjoin each other along zones of seismic activity.

PLATONIC SOLIDS: The convex geometric shapes that have for their sides or facets identical polygons with sides of equal lengths. Polygons are flat shapes whose sides consist of straight line segments. Familiar polygons having sides with equal length are the square, pentagon, and equilateral triangle. Only five solid shapes having such shapes as sides or facets are possible, namely the five Platonic solids. The two most familiar Platonic solids are the cube and the tetrahedron (four-sided pyramid).

PLUTONISM: In modern geology, the hardening of magma far below the surface to form igneous rock; granite, for example, is formed by plutonism.

P-N JUNCTION: In electronics, devices of microscopic size can be made by adding small amounts of dopant or contaminant substances to portions of a semiconducting crystal, usually silicon. Some dopants lack electrons and so contribute positive charges to the crystal; others have extra electrons and so contribute negative charges. Positive dopants are termed p-type, negative dopants n-type. Where a p-type region abuts or contacts an n-type region, a p-n junction is created. Electrons from the n-type side of the junction are drawn to the positive charges on the p-type side until electrostatic forces balance out and prevent further charge movement. This creates a slab-shaped region of electric neutrality along the p-n junction. Since this region is depleted of charge carriers, it is termed a depletion zone and cannot carry current. Placing a voltage across the p-n junction that is positive on the p side narrows the depletion zone and allows current to flow through it; applying voltage that is negative on the p side widens the depletion zone so that current cannot flow. A p-n junction thus allows one-directional current flow. Used in this fashion, a p-n junction is termed a diode.

PNEUMA: In the Stoic philosophy of ancient Greece, a person's spirit or life-force. More generally, this word referred to the inhaled and exhaled breath. In modern medical terminology it is the root of lung-related terms such as pneumonia.

POISEUILLE'S CAPILLARY FLOW FORMULA: A mathematical statement relating the volume and velocity of liquid flow through a tube to the tube's diameter, the pressure at both ends, and viscosity (liquidity) of the fluid. It was created by French physician Jean Poiseuille (1799–1869) in the 1840s.

POLARIMETER: An instrument for measuring the polarization of light, that is, the way in which its transverse electromagnetic fields have been restricted to vibration in specific directions.

POLE STAR: The Pole Star is Polaris, a visible star that happens to be aligned with Earth's spin axis so that all the other stars appear to spin around Polaris while it remains fixed. Polaris is visible only in the Northern Hemisphere. In the Southern Hemisphere, no visible star happens to be aligned with Earth's axis, so there is no southern Pole Star.

POLIO: A disease (*poliomyelitis*) caused by a virus (poliovirus [PV]) that can result in muscle weakness, paralysis, or death.

POLYETHISM: In social insects such as ants and bees, the specialization of various individuals for

different functions—queen, worker, drone, and so forth. Polyethism can be either morphological (individuals with different specializations have different anatomies) or temporal (individuals of different ages can be assigned different functions). Temporal polyethism is the main form of polyethism in honeybees.

POLYGENIC: In genetics, a trait in an organism that is controlled by more than one gene. Most complex traits are polygenic to the extent that they are gene-controlled. (Almost all gene expression is also influenced by environmental factors such as diet, stress, usage, and the like.)

POLYGENY: In evolutionary biology, the obsolete theory that different human races (also a questionable concept, biologically) had separate evolutionary origins. In genetics, polygeny occurs when a single trait in an organism is controlled by more than one gene, i.e., is polygenic.

POLYGYNY: Having more than one wife; a society where this pattern prevails is polygynous. An approximate synonym for polygyny is polygamy; however, polygamy usually describes having more than one wife in a context (e.g., U.S. law) where this is aberrant or criminal relationship, while polygyny tends to denote a socially accepted practice.

POLYMATH: Any person who is highly capable in several fields of knowledge—for example, physics, mathematics, and music.

POLYPHYLETIC: Term applied to a group of organisms that does not include the most recent common ancestor of those organisms; the ancestor does not possess the character shared by members of the group.

POLYSACCHARIDE: A molecule that consists of several sugar molecules linked together in a long chain of multiple monosaccharides.

POPULATION: A complete set of individuals, objects, or events that belong to some category.

POPULATION GENETICS: The study of changes in gene frequency (the number of organisms possessing a certain version of a gene) in populations. Gene frequencies are affected by random drift, natural selection, founder effect, and other factors.

POPULATION INVERSION: In physics, a population inversion occurs when a greater number of atoms or molecules in a system are in a high-energy state than are in a low-energy state. In a laser, high-energy atoms in a laser medium featuring population inversion emit the coherent photons of laser light.

PORTOLAN CHARTS: Navigational charts produced in Europe and elsewhere during the Middle Ages.

POSITIVISM: The philosophical doctrine that only science can produce valid knowledge. According to positivism, there is no other source of knowledge but science (e.g., religion, intuition, common sense, etc.). This view was first articulated by French philosopher August Comte (1798–1857).

POSITRON: The antiparticle of the electron. It has the same mass and spin as the electron, but its charge, though equal in magnitude, is opposite in sign to that of the electron.

POST HOC: Latin for "after this." The phrase is often used to label a common error in reasoning, namely the assumption that because event B happens after event A, it must have been caused by event A. The error is tempting because when A does actually cause B, B always does follow A; however, B may follow A even when it is not caused by A. In the latter case, the fact that B follows A may be coincidence or occur because both are caused by some third thing C. The corrective to the post-hoc fallacy is sometimes stated as "Correlation does not prove causation," i.e., just because things happen together, are correlated, it does not necessarily mean that one is causing the other.

POSTMODERNISM: A style of thought that tends to reject the belief that any qualities possessed by human beings are inherent in their nature, an idea that postmodernists call essentialism. It also emphasizes that all belief systems, including science, are shaped by relationships of "power," that is, the power held by some human beings over others.

POSTULATE: To postulate is to propose the existence of a thing or rule for the purpose of enabling a chain of reasoning. Generally, postulates are simple propositions that are self-evident or nearly so.

PRAGMATISM: The philosophical doctrine that holds that the truth-value of an idea relates to its practical usefulness; if adopting an idea leads to useful results, the idea can, according to pragmatism, be deemed "true," or at least more true than other ideas that lead to less-useful results.

PRECAMBRIAN: All geologic time before the beginning of the Paleozoic era. This includes about 90% of all geologic time and spans the time from the beginning of Earth, about 4.5 billion years ago, to 544 million years ago. Its name means "before Cambrian."

PRIME MERIDIAN: A meridian is a circle drawn around a planet and passing through its north and south poles; the prime meridian is the meridian arbitrarily (i.e., for no necessary reason) named as the 0th meridian, the one from which numbering of the other meridians shall begin. For example, on Earth, the prime meridian passes through Greenwich, England; on Mars, it passes through the center of crater Airy-0 (zero), selected for that purpose in 1969.

PRIMORDIAL CLOUD: In astronomy, any cloud of dust and gas from which a star, solar system, galaxy, or star cluster condenses under the mutual gravitational attraction of its particles. Often, the cloud from which our own solar system condensed is referred to as "the" primordial cloud.

PRION: A protein having correct chemical composition but a misfolded shape that is capable of inducing similar, normally-folded proteins to become misshapen. Prions are not alive but can cause infectious disease because, if ingested (e.g., by eating meat), they can trigger the formation of misshapen proteins in a previously uninfected organism. The body's chemical mechanisms for removing the normally-folded version of the protein do not work, so masses of the misfolded proteins accumulate in nerve tissues, eventually causing mental breakdown and death. In humans, infection by prions causes variant Creutzfeldt-Jakob disease.

PRISM: A triangular or wedge-shaped block of glass that breaks up light into its constituent colors.

PROBABILITY: The degree of chance that something might happen.

PROKARYOTE: An organism (usually single-celled) with a cell or cells that lack a true nucleus, which is a saclike structure that contains the cell's DNA and associated proteins. In prokaryotes, DNA floats freely about the interior of the cell. Bacteria and archaea are prokaryotes; single-celled or multicellular organisms that have a cell nucleus are called eukaryotes.

PROPER MOTION: The movement of stars across the sky caused by their relative motion to Earth.

PROTEIN: A complex chemical compound that consists of many amino acids attached to each other that are essential to the structure and functioning of all living cells.

PROTEOMICS: Proteomics is a discipline of microbiology and molecular biology that arose from the gene sequencing efforts that culminated with the publication of the sequence of the human genome in 2001. In addition to the human genome, sequences of disease-causing bacteria and other microorganisms continue to be deduced, although fundamental knowledge of the sequence of nucleotides that comprise deoxyribonucleic acid (DNA) reveals only a portion of the encoded protein structure. Proteins are an essential element of bacterial structure and function; for example, a variety of proteins enable a microorganism to establish and maintain an infection. Thus, knowledge of the three-dimensional structure and associations of proteins is vital for a full understanding of microorganism behavior and operation. Proteomics is an approach to unravel the structure and function of proteins.

PROTOCONTINENT: A landmass that is in the process of being developed by geological processes into a true or major continent.

PROTON: Particle found in a nucleus with a positive charge. The number of these gives the atomic number.

PROXIMATE: Nearby. For example, the closest star to our sun is Proxima Centauri, about 4.22 light years away.

PSEUDOSCIENCE: Arguments or ideas, often laced with scientific terminology or bizarre calculations, based on theories developed outside of the scientific method and thus not subject to scientific validation.

PSYCHIATRY: The branch of medicine dealing with the study of the mind and the diagnosis, treatment, and prevention of emotional and behavioral disorders.

PSYCHOANALYSIS: The method of analyzing psychic phenomenon and treating emotional disorders that involves treatment sessions during which the patient is encouraged to talk freely about personal experiences, especially about early childhood and dreams.

PSYCHOLOGY: The study of the mind, especially as it relates to behavior.

PSYCHROMETER: An instrument designed to measure dew point and relative humidity, consisting of two thermometers (one dry bulb and one wet bulb). The dew point and humidity levels are determined by drying the wet bulb (either by fanning or whirling the instrument) and comparing the difference between the wet and dry bulbs with preexisting calculations.

PULSAR: A rapidly rotating neutron star that has a strong magnetic field.

PULSED LASER: Lasers may either be operated continuously or in bursts. Those that are kept on for

relatively long intervals are termed continuous lasers, and those that are turned on in brief flashes or bursts are termed pulsed lasers. Pulsed lasers can produce extremely brief pulses, on the order of a few femtoseconds (a femtosecond is a millionth of a billionth of a second, 1×10^{-15} second).

PUMPING: In lasers, the provision of energy to the laser medium; some of this energy is converted by the laser medium to coherent (phase-matched) laser light. Pumping may be accomplished using light, electric current, or chemical reactions.

PUNCTUATED EQUILIBRIUM: A model of evolution in which change occurs in relatively rapid bursts, followed by longer periods of stasis.

PURE MATHEMATICS: The pursuit and expansion of mathematical knowledge and technique without regard to whether the mathematics produced will ever have a technological application. Pure mathematics is often contrasted with applied mathematics. Often, pure mathematics has turned out to have unforeseen applications.

PURGE: In power politics, a campaign to remove (often violently) persons of certain ethnic backgrounds or beliefs from a government agency or other segment of the population. In medicine, to purge is to empty the bowels by taking a laxative.

PYRHELIOMETER: An instrument for measuring the intensity of solar radiation received at Earth's surface. The Eppley pyrheliometer measures not only the intensity but the duration of solar radiation, allowing the total insolation (exposure to the sun) at the instrument's location over a given period to be calculated.

Q

QUADRANT: One of the four regions in the Cartesian coordinate system formed by the intersection of the x- and y-axes.

QUANTUM: Something that exists in discrete units.

QUANTUM MECHANICS: A system of physical principles that arose in the early twentieth century to improve upon those developed earlier by Isaac Newton (1643–1727), specifically with respect to submicroscopic phenomena.

QUANTUM NUMBER: A variable in quantum mechanics that specifies the state of electrons in an atom.

QUANTUM PHYSICS: Quantum physics, also called quantum mechanics, is the science of the behavior of matter and energy at any scale where their quantum nature is significant (which is usually, though not always, the atomic or subatomic scale). The quantum nature of matter and energy refers to the restriction of changes to definite, sudden steps rather than smooth passage through a range of in-between values. Quantum physics began to be developed in the early twentieth century and continues to be one of the most vigorously investigated areas of physics.

QUANTUM TUNNELING: The appearance of a particle on the other side of a barrier (e.g., an electric field) that it does not have the energy to overcome. Tunneling occurs because every particle can be potentially observed at all points in the universe at any future time, only with much slighter probability at points far from its nominal location; if a particle is close to a barrier, then by the laws of quantum physics it can, with a certain probability, simply appear on the other side of the barrier without ever having energy enough to get over. It is as if a motionless marble sitting in a cup suddenly appeared on the table beside the cup—indeed, the probability of this event, although very small, is not, according to quantum physics, zero. Quantum tunneling is used in some microelectronic devices, such as tunnel diodes.

QUARANTINE: The practice of separating people who have been exposed to an infectious agent, but have not yet developed symptoms, from the general population. This can be done voluntarily or involuntarily by the authority of states and the federal Centers for Disease Control and Prevention.

QUARKS: Subatomic elementary particles that combine in threes to form other particles (neutrons, protons, and others) and are never observed alone. Quarks come in six varieties or flavors—the term is arbitrary and has nothing to do with the sense of taste—namely, charm, strange, top, bottom, up, and down.

QUASAR: A small, powerful source of energy that looks like a star but is believed to be the active nucleus of a distant galaxy.

R

RACEMIC: In optics, some transparent compounds rotate polarized light to the right (dextrorotatory compounds); others rotate it to the left (levorotatory compounds). A racemic substance is a mixture

of equal parts of dextrorotatory and levorotatory compounds.

RADIATION: Energy transmitted in the form of electromagnetic waves or subatomic particles.

RADIATION THERAPY: Use of radioactive substances to kill cancer cells in the human body.

RADIATIVE FORCING: A change in the balance between incoming solar radiation and outgoing infrared radiation. Without any radiative forcing, solar radiation coming to Earth would continue to be approximately equal to the infrared radiation emitted from Earth. The addition of greenhouse gases traps an increased fraction of the infrared radiation, reradiating it back toward the surface and creating a warming influence (i.e., positive radiative forcing) because incoming solar radiation will exceed outgoing infrared radiation.

RADICAL THEORY: Also called the free-radical theory. In chemistry, the idea, first proposed in the 1950s, that aging is the result of accumulated biochemical damage to body cells from free radicals, charged atoms or molecules with a strong tendency to participate in chemical reactions (beneficial or not). The theory is not widely accepted among biologists studying aging, though there is agreement that free radicals can cause some disease conditions that progress with age.

RADIO GALAXY: A galaxy with an active nucleus that shines brightly in radio wavelengths.

RADIOACTIVE DECAY: The predictable manner in which a population of atoms of a radioactive element spontaneously disintegrates over time:

RADIOACTIVITY: The property possessed by some elements of spontaneously emitting energy in the form of particles or waves by disintegration of their atomic nuclei.

RADIOMETRIC DATING: The use of naturally occurring radioactive elements and their decay products to determine the absolute age of the rocks containing those elements.

RADIOMETRY: The measurement of optical electromagnetic radiation, which is defined as electromagnetic radiation in the frequency range of 3×10^{11} and 3×10^{16} Hz (cycles per second). Optical radiation includes visible light but is not limited to it.

RADIOSONDE: An instrument for collecting data in the atmosphere and then transmitting that data back to Earth by means of radio waves.

RANKING: An ordering of things or variables in some linear order according to some standard of comparison, first to last or highest to lowest. Nonparametric statistical analysis often deals with rank data such as letter grades in academic settings or place winners in sports.

RAREFACTION: A decrease in density. Also, a region of space with a lower-than-normal density. Particularly, a region of low density in a sound wave traveling through a gas such as air.

RATIONALIST PHILOSOPHERS: All philosophers who privilege or emphasize the use of reason in the quest for truth, while downplaying faith, experience, intuition, or other ways of knowing. Non-rationalist philosophers are not, in general, anti-reason, but see reason as one mode of mental activity leading to knowledge or wisdom, rather than as the only admissible one.

RECAPITULATION: In nineteenth-century and early twentieth-century evolutionary biology, the idea that animal embryos replay or recapitulate the evolutionary history of their ancestors (their phylogeny) during individual growth (ontogeny) was commonplace. The idea, often called simply recapitulation or the biogenetic law, was first popularized in 1866 by German biologist Ernst Haeckel (1834–1919) and is often summed up in the phrase "Ontogeny recapitulates phylogeny." However, it was soon discredited by biologists and is now known to be untrue, although in some cases certain features of ancestral development do appear as traces in embryonic development.

RECOMBINANT DNA: DNA that is cut using specific enzymes so that a gene or DNA sequence can be inserted.

REDSHIFT: The lengthening of the frequency of light waves toward the red end of the visible light spectrum as they travel away from an observer; most commonly used to describe movement of stars away from Earth.

REDUCTION: A process in which a chemical substance gives off oxygen or takes on electrons.

REDUCTIONISM: A style of thought that can be contrasted to holism. Reductionism assumes that the properties of any complex system—a human brain, an ecosystem, or other—can be reduced (hence "reductionism") to the interactions of its component parts. Holism asserts that at least some system properties arise out of the system as a whole (hence "holism") and are not possessed by, or reducible to, the properties of the system's isolated, individual parts.

REEF: A large ridge or mound-like structure within a body of water that is built by calcareous organisms such as corals, red algae, and bivalves. A barrier reef is a reef growing offshore from a land mass and separated by a lagoon or estuary, e.g., the Great Barrier Reef of Australia. A patch reef is a discontinuous reef growing in small areas, separated by bare areas of sand or debris, often part of a larger reef complex.

REFLECTING TELESCOPE: A telescope that uses mirrors to form a magnified image of distant objects rather than lenses (as is done in a refracting telescope).

REFORMATION: The Reformation was a movement for reform of the Roman Catholic Church that began in Germany in the early 1500s and led, eventually, to the establishment of Protestantism.

REFRACTING TELESCOPE: A telescope that uses lenses to form a magnified image of distant objects rather than mirrors (as is done in a reflecting telescope).

REFRACTION: The deflection from a straight line of a light ray or other energy beam when passing from one optical medium (such as air) to another (such as glass) in which its velocity is different.

RELATIVISM: In philosophy, the belief that moral and aesthetic values—beliefs about right/wrong and beauty, respectively—have no independent or ultimate truth or falsehood, but are defined relative to particular societies. A relativist will argue that what is wrong or ugly in one society may be right or lovely (or at least unimportant) in another society.

RELATIVITY THEORY: Relativity theory is actually a pair of theories, special relativity and general relativity, that were first proposed by German physicist Albert Einstein (1879–1955) in 1905 and 1915, respectively. Special relativity describes the effects of unaccelerated (constant-speed) straight-line motion on mass, length, and the flow of time; one consequence of special relativity theory is that mass and energy are interchangeable. General relativity describes accelerated and curved-line motion and the curvature of space by mass, which accounts for the force of gravity. Both theories are used throughout modern physics and astronomy and in some engineering applications (e.g., general relativity is applied in global positioning system [GPS] technology). Although relativity theory has been tested thousands of times against observations and experiments and found to be highly accurate, it has not yet (as of 2008) been united with quantum mechanics, a major challenge of modern physics.

RENAISSANCE: In the 1400s through the 1600s, a revival of interest in classical (Greek and Roman) art, philosophy, and literature triggered many changes in European culture; although this period is often termed the Renaissance, historians do not all agree that the period was actually distinct enough from preceding and following times to merit designation as a separate period. The term "Renaissance" (French for rebirth), which was popularized as a label for this period in the nineteenth century, implies that the immediately preceding period was senile or dead, which is not asserted by most modern historians.

RENORMALIZATION: A mathematical method in quantum physics first proposed in 1947 to deal with apparently absurd infinities in the equations of the theory known as quantum electrodynamics. In renormalization, infinities of opposite sign (positive and negative) are allowed to cancel each other out, producing a finite result that matches observation.

REPRODUCTIVE CLONING: A type of cloning that involves somatic cell transfer to induce pregnancy. This type of cloning requires a surrogate mother.

RESECTION: The surgical cutting out of part of an organ.

RESOLUTION: The ability of a sensor to detect objects of a specified size. The resolution of a satellite sensor or the images that it produces refers to the smallest object that can be detected.

RESOLVE: To examine a celestial object through a telescope and find that it is composed of stars.

RESONATOR: Any device that vibrates at a certain favored frequency (resonates). In acoustics and radio engineering, resonators are often hollow cavities that trap waves of a certain length.

RESTORATION ECOLOGY: The subdiscipline of ecology that studies how damaged ecosystems can be restored to something approximating their original condition.

RESTRICTION ENZYME: A special type of protein that can recognize and cut DNA at certain sequences of bases to help scientists separate out a specific gene. The enzymes are used to generate fragments of DNA that can be subsequently joined together to create new stretches of DNA.

RESURRECTIONIST: In England in the early nineteenth century, a resurrectionist or resurrection man was a person who illegally dug up recently buried corpses for sale to medical schools so that medical

students might dissect them. The only legal source of corpses at that time was the execution of murderers, but executions had declined, so demand exceeded supply until 1832. In that year, Parliament passed the Anatomy Act, which allowed some other types of corpses to be used for medical dissection.

RETROGRADE MOTION: All planets in our solar system appear to move across the sky relative to the fixed stars. Most of the time they appear to move from west to east, opposite to the sun and moon; however, periodically, due to differences between Earth's orbital motion and theirs, they appear to switch direction and move from east to west. They do not actually reverse direction, but appear to do so. This reversed motion is termed retrograde motion.

RETROROCKET: A rocket fired against the direction of travel of a spacecraft orbiting a planet or moon in order to decrease its velocity and lower its orbit.

RETROSPECTIVE STUDIES: Also called retrospective cohort studies or historical studies. Medical studies in which researchers study the medical records of patients to determine the health influence of diet or some other factor that varies from one patient to another. Such a study is termed retrospective because the patients were not selected with a view to the study, but are studied in retrospect because they happen to be available.

RETROVIRUS: Viruses in which the genetic material consists of ribonucleic acid (RNA) instead of the usual deoxyribonucleic acid (DNA). Retroviruses produce an enzyme known as reverse transcriptase that can transform RNA into DNA, which can then be permanently integrated into the DNA of the infected host cells.

RIBONUCLEIC ACID (RNA): A long, twisted molecule that, similar to DNA (deoxyribonucleic acid), encodes information along its length as a series of molecular subunits (nucleotides). In most cells, information is copied off DNA onto RNA molecules, which are then transported to other parts of the cell and used as templates or blueprints for manufacturing proteins. The earliest forms of life probably used only RNA as their hereditary material; this hypothetical stage of life's history is termed the RNA world. DNA resembles a ladder, with two spiraling side-pieces linked by rungs; RNA resembles a piece of DNA cut lengthwise, a single side-piece with a series of half-rungs hanging off the side.

RIBOSOME: An organelle, that is, a small structure found inside cells. Information from DNA in the cell nucleus is copied to messenger RNA (mRNA) molecules and passed to the ribosomes, which use the mRNA as a blueprint for the manufacture of proteins.

RIBOSOMES: Organelles that play a key role in the manufacture of proteins. Found throughout the cell, ribosomes are composed of ribosomal ribonucleic acid (rRNA) and proteins. They are the sites of protein synthesis.

RIGHT TRIANGLE: A triangle that contains a 90°, or right, angle.

ROCKET: A machine that burns fuel and oxidizer in a combustion chamber and squirts the resulting hot, expanding gases out a nozzle at high speed. As described by Newton's Third Law of Motion, the force that accelerates the gas out of the nozzle is balanced by an equal and opposite force acting against the combustion chamber. This reactive force accelerates the rocket in the opposite direction to the gas.

RUBY: A precious crystalline stone, reddish and translucent when cut and polished, chemically consisting of aluminum oxide plus chromium (Al_2O_3Cr). It was used in some early lasers as the laser medium.

S

SALVARSAN: A synthetic agent used to cure syphilis, introduced in 1911.

SATISFICING: An economics term invented by Nobel Prize-winning economist and artificial intelligence researcher Herbert Simon (1916–2001). It refers to decision-making behavior that does not seek a perfect outcome or solution, but rather seeks a result that is merely satisfactory. Much real-world decision-making takes the form of satisficing rather than of perfect optimizing.

SCANNING ELECTRON MICROSCOPES (SEM): Devices that illuminate a target with a beam of electrons in order to produce highly magnified images of them. The name of the device refers to the fact that it scans a narrow electron beam back and forth over a sample to build up an image. Some scanning electron microscopes can image features as small as 1 nanometer (1 billionth of a meter).

SCANNING PROBE MICROSCOPE: Devices that produce highly magnified images of objects by moving a finely-pointed probe near their surface without

touching it. The name of the device refers to the fact that it scans the probe back and forth over a sample to build up an image. Some scanning probe microscopes can image features as small as a single atom.

SCHIZOPHRENIA: A serious mental illness characterized by isolation from others and thought and emotional disturbances.

SCIENTIFIC JOURNAL: A periodical that contains articles that have been reviewed by expert scientists before being accepted for publication. Journals that publish opinions about science or that look scientific but have not been peer-reviewed by recognized scientists with relevant expertise are not scientific journals.

SCIENTIFIC METHOD: Collecting evidence meticulously and theorizing from it.

SCRIBE: In various ancient cultures (e.g., Egypt), a literate person employed to write and read documents for religious, legal, and business purposes. In ancient times the ability to read and write was a rare skill, and the scribe was a valued professional. More generally, any person who copies documents by hand in any historical period can be termed a scribe.

SEARCH ENGINE: Computer programs that search for specific strings of characters in memory. The most commonly used search engines are those that search the World Wide Web (e.g., Safari, Explorer, Firefox, Flock).

SEMICONDUCTOR: Substance, such as silicon or germanium, whose ability to carry electrical current is lower than that of a conductor (like metal) and higher than that of insulators (like rubber).

SENSITIVE DEPENDENCE ON INITIAL CONDITIONS: In a chaotic system, the future state of the system—what orbit a comet ends up following a million years from now, for example—can vary greatly depending on very slight changes in the original state of the system. The original conditions of the chaotic system are termed its initial conditions, and the future state is said to depend sensitively on the initial conditions.

SEPSIS: Also called bacteremia. A bacterial infection in the bloodstream or body tissues. This is a very broad term covering the presence of many types of microscopic disease-causing organisms. Closely related terms include septicemia and septic syndrome. According to the Society of Critical Care Medicine, severe sepsis affects about 750,000 people in the United States each year. However, it is predicted to rapidly rise to one million people by 2010 due to the aging U.S. population. Over the decade of the 1990s, the incident rate of sepsis increased over 91%.

SERUM: The clear, thin, sticky fluid of the blood that contains no cells or platelets.

SERUM SICKNESS: An allergic reaction to an antiserum, which is a preparation of the clear fraction of blood (serum) containing antibodies for a specific disease and administered as a vaccine.

SESSILE: Any animal that is rooted to one place. Barnacles, for example, have a mobile larval stage of life and a sessile adult stage of life.

SET: A collection of objects, physical or abstract.

SEVERE ACUTE RESPIRATORY SYNDROME (SARS): SARS is a severe respiratory infection caused by the SARS coronavirus. It has an unusually high mortality rate (death rate among those infected) for an infectious disease, almost 10%.

SHELL MODEL OF THE NUCLEUS: Also known simply as the shell model. A mathematical description of atomic nuclei in terms of the energy levels permitted by quantum mechanics to its neutrons and protons. The model was first proposed in 1949 and has been refined since.

SINGULARITY: In physics, a point in space-time where matter has infinite density and gravitational force is infinite—at least as described by the equations of general relativity. In mathematics, any point near which a function goes to infinity (that is, is undefined) may be termed a pole or singularity.

SOCIOPATHY: A psychological disorder characterized by extreme hostility to other persons and lack of conscience (the sense of right and wrong).

SOLAR MASS: A unit of mass measurement for stars; equivalent to the sun's mass.

SOLAR PROMINENCES: Loop- or arch-shaped masses of hot, luminous gas that often form above the sun's surface, shaped by intense magnetic fields. They may persist for days or weeks and span thousands of miles.

SOLID STATE PHYSICS: All physics devoted to the properties of solids—substances that retain a fixed shape unless subjected to sufficient force—fall under the heading of solid-state physics.

SOMATIC CELL: A cell that is part of the body (Greek, *soma*). Somatic cells are distinguished from

germline cells (sperm and egg cells), which are directly involved in reproduction. All somatic cells except red blood cells (which contain no DNA) contain two copies of the organism's DNA; germline cells contain only one copy. When two germline cells unite, they produce a somatic cell (fertilized egg) with the usual two copies, which then divides and re-divides, duplicating its DNA at every step, as the organism grows.

SOUTHERN OCEAN: Also called the Antarctic Ocean. That part of the world ocean found south of 60° south latitude, ringing the continent of Antarctica.

SOY: Soy, also called soybean, is a legume native to Asia. Over 200 million tons of soybeans are harvested yearly worldwide. Processing of soybeans yields edible flour, oil, and curd (tofu). Soybean oil is also used in a wide variety of waxy or oily industrial products.

SPACE: The set of points that can be occupied by objects. Its properties are described by physicists in terms of geometry: space is not composed or made of any more fundamental material. In general relativity, space has three dimensions: that is, each point in space can be specified by three numbers representing distance measurements. In mathematics and computer science, all labeled measurements or quantities can be considered dimensions, and any collection of dimensions, however numerous or whatever their nature, can be termed a "space."

SPACE-TIME: The four-dimensional realm of space (which has three dimensions, often termed length, width, height) plus time (a fourth dimension). Time and space are neither independent nor interchangeable, but form a stretchy background, realm, or setting in which physical events occur. The term "stretchy" here refers to the fact that motions in space give rise to differences in time flow for moving and stationary observers: There is no one, unique rate of time flow throughout space, and no universal present moment. In particular, as described by special relativity, any stationary observer of a moving clock will see that clock as running slower than one to which they are attached. Here, "stationary" is a relative term because an observer attached to the "moving" clock will see exactly the same situation in reverse: Either observer's point of view can just as well be termed stationary (or moving) as that of the other. General relativity describes how space-time is curved by matter, giving rise to gravitation.

SPECIAL RELATIVITY: The theory proposed in 1905 by German physicist Albert Einstein (1879–1955) that describes the effects of straight-line, unaccelerated motion on time, distance, and mass. According to the theory, which has been validated by thousands of experiments, observers in constant, straight-line motion with respect to each other see that the other's mass is increased, their size in the direction of travel is decreased, and their clocks run slower. These effects are real, not illusory. The equivalence of mass and energy, which powers nuclear weapons and stars, follows from the theory. It is incorporated into the more complex and far-reaching theory of general relativity, proposed by Einstein in 1915 and also validated by many experiments.

SPECIATION: Speciation is the process by which new species arise. Although there are a variety of definitions, all involve an isolation event that separates an interbreeding population until the daughter lineages evolve in separate trajectories.

SPECIES: A group of living things that can breed together in the wild.

SPECIFIC HEAT: Also known as its specific heat capacity. The amount of heat energy required to raise one unit mass of that substance by a fixed unit of temperature (usually 1° Celsius). It takes more energy to heat substances that have high specific heats.

SPECTRAL LINE: A spectrum is a graph of the frequencies found in a mixture of waves, such as light waves. The graph line is higher at frequencies where more energy is present; when energy is concentrated in a narrow range of frequencies, the line draws a spike or vertical line. For example, a pure blue light appears as a spectral spike or line in the blue part of the visible light spectrum. Alternatively, lines can appear as narrow notches in an otherwise continuous-appearing spectrum. These notches are called absorption lines because they usually represent frequencies that have been absorbed after light was emitted by some source, such as the sun.

SPECTROSCOPE: An instrument used to measure the absorption, scattering, or emission patterns of electromagnetic radiation by atoms or molecules.

SPECTROSCOPY: Spectroscopy is the measurement of the absorption, scattering, or emission of electromagnetic radiation by atoms or molecules. The process separates the light of an object (generally, a star) into its component colors so that the various elements present within that object can be identified.

SPECTRUM: The dispersion of light into differential wave forms (e.g., blue light, red light).

SPERM: A mature male sex cell secreted in semen during male ejaculation.

SPHERICAL ABERRATION: The focusing of different colors at different distances from the lens rather than at a single image plane.

SPIRAL NEBULA: A distant, spiral-shaped collection of stars that appears cloudy without a telescope.

SPONTANEOUS GENERATION: Also known as abiogenesis; the incorrect theory that living things can be generated from nonliving things.

STABILITY: The quality or property of remaining in one state until forcefully disturbed. For example, a pyramid standing on its base is stable, but a pyramid balanced on its point is unstable. The distinction between stable and unstable systems appears throughout technology and the sciences.

STAGING: In rocketry, the practice of dividing a missile or spacecraft that is to be launched from the ground into separable components (stages). Each stage has its own fuel tanks and rocket motors. As a staged rocket ascends, it consumes the fuel in the tanks of its bottommost stage; when that stage is empty, it is dropped and the next stage is ignited. Each successive stage is much smaller than the previous one. The advantage of staging is that the weight of empty (now-useless) tanks does not need to be lofted into orbit.

STANDARD CANDLE: An astronomical object whose absolute magnitude (known luminosity) and apparent magnitude (observed brightness) are known, and which can therefore have its distance determined.

STANDARD MODEL: In particle physics, the theory that describes the fundamental particles that make up ordinary matter and the particles that are exchanged between them to create all of the fundamental forces except gravity. Gravity is not described by the Standard Model but by the theory of general relativity; scientists hope to someday modify the two so that they can be united into a single theory that describes all known phenomena.

STATISTICS: The branch of mathematics that deals with the analysis of large numbers of measurements (quantitative data).

STELLAR MAGNITUDE: The brightness of a star. The brightest stars in the sky are first magnitude, and dimmer stars have higher magnitude numbers.

STEM CELL: An unspecialized cell in an embryo or adult that has the potential to divide and grow into other types of specialized cells or tissues in the body. Stem cells give rise to cells that have specialized forms and functions such as nerve or muscle cells.

STEREOCHEMISTRY: The branch of chemistry that deals with the way the three-dimensional shapes of molecules (stably bound clusters of atoms) affect their properties.

STEREOISOMER: Two molecules that contain the same numbers of the same types of atoms but differ in the spatial arrangement of those atoms are stereoisomers of each other.

STIMULATED EMISSION: The process of emitting light in which one photon stimulates the generation of a second photon, which is identical in all respects to the first.

STOICS: The Greek philosopher Zeno (334–262 BC) founded the Stoic school of philosophy in Athens, Greece, in the third century BC. The name "Stoic" arose from the fact that Zeno taught in the Stoa, a pillared, roofed walkway. The Stoics taught that happiness could be achieved by mastering passion (any form of strong feeling) and becoming virtuous.

STRANGE ATTRACTOR: In the mathematical description of systems, an attractor is a state that the system tends to approach over time. For example, a state of regular back-and-forth swinging is an attractor for a playground swing or pendulum that is being regularly pushed. A strange attractor is a state that does not repeat itself with such perfect regularity as a swinging pendulum; rather, the system may assume a never-repeating series of states that are close to the attractor but never simply converge to it.

STRATIGRAPHY: The branch of geology that deals with the layers of rocks or the objects embedded within those layers.

STREAMLINES: In the physics of flowing fluids, curves that show the paths followed by particles in different parts of the flow. For a fluid moving smoothly through a curved pipe, the streamlines would be lines inside the fluid that parallel the curvature of the pipe. In principle, an infinite number of streamlines could be drawn inside any body of flowing fluid.

STEREOISOMERISM: Two molecules that contain the same numbers of the same types of atoms but differ in the spatial arrangement of those atoms are stereoisomers of each other; the occurrence of stereoisomers is termed stereoisomerism.

STROMATOLITES: The bulb- or pillow-shaped rocky masses formed by some blue-green algae in shallow

ocean water. Some fossil stromatolites are among the oldest traces of life on Earth; the oldest known stromatolites that were definitely formed by biological processes are 2.7 billion years old.

STRONG FORCE: In atomic physics, one of the four fundamental forces of nature (electromagnetic, weak, strong, gravitational). The strong force is repulsive at extremely close range (much smaller than an atomic nucleus) and attractive at longer ranges. Within the atomic nucleus, the attraction of the strong force between protons is stronger than the repulsive electromagnetic force between them (like charges repel); this is why atomic nuclei are not blown apart by the mutual electromagnetic repulsion of their positively-charged protons. On the other hand, protons and neutrons are kept from simply collapsing into each other by the repulsive effect of the strong force at extremely short range. At longer-than-nuclear ranges, the Coulomb force of electromagnetic attraction or repulsion is far stronger than the strong nuclear force, so it dominates outside the nucleus.

STRUCTURAL THEORY: In chemistry, the view, first put forward in the mid-nineteenth century by Russian chemist Aleksandr Butlerov (1828–1886), that the properties of a chemical substance arise both from the atoms that make it up and the way those atoms are structured to form molecules. That is, according to the structural theory, not only the composition but the shape of a molecule matters.

SUBDUCTION: Tectonic process that involves one plate being forced down into the mantle at an oceanic trench, where it eventually undergoes partial melting.

SUBLIMATION: Transformation of a solid to the gaseous state without passing through the liquid state.

SUBORBITAL: A rocket flight that passes above the atmosphere into space but does not achieve an orbit around Earth. The first American in space, Alan Shephard (1923–1998), made a suborbital flight on May 5, 1961, from Cape Canaveral space center in Florida (later Cape Kennedy) to a height of 116 miles (187 km), landing in the Atlantic 302 miles (486 km) from his launch point.

SUCCESSION: In ecology, succession refers to the replacement of certain plant and animal species by others in the process of regrowth over land disturbed by fire, logging, or other causes. The nature of succession in any given place depends on the local environment. In areas that are naturally forested, succession typically involves colonization by weeds, then fast-growing shrubs, then softwood trees such as aspens, and finally large, long-lived trees.

SUGAR: Any of several small carbohydrates, such as glucose, that are sweet to the taste.

SULCI: In medicine, the term "sulcus" (plural sulci) refers to one of the grooves or valleys in the surface of the brain formed by the folding of its surface. In astronomy, sulci are groove-like formations on the surface of a planet or moon.

SULFONAMIDES: Synthetic antibacterial agents produced in the 1930s.

SUNSPOT: A region on the surface (photosphere) of the sun that is temporarily cool and dark compared to surrounding areas.

SUPERCONTINENT: In geology, a supercontinent is formed when Earth's 14 or so major tectonic plates, which are in constant motion, happen to come together in a single, large landmass, leaving the rest of the planet covered with ocean. At least half a dozen supercontinents have formed during Earth's 4.5-billion year history.

SUPERFLUOUS: Anything which is unnecessary or more than needed for some purpose.

SUPPURATION: Formation and discharge of pus.

SYMBIOSIS: A pattern in which two or more organisms live in close connection with each other, often to the benefit of both or all organisms.

SYMPATHETIC NERVOUS SYSTEM: A collection of nerve cells that control a variety of internal functions when the body is exposed to stressful conditions.

SYMPLESIOMORPHY: In evolutionary biology, the occurrence of a similar trait in two or more taxa (groups of organisms) because those taxa all share a common ancestor from which they have inherited the trait.

SYNAPOMORPHY: An expressed character which, because it is shared by members of a classification taxa, is used to infer common ancestry.

SYNAPSE: Junction between nerve cells in the brain through which neurotransmitters travel and where the exchange of electrical or chemical information takes place.

SYNCHROTRON RADIATION: Radiation emitted by charged particles accelerated in magnetic fields to speeds near the speed of light, usually detected as radio wavelengths.

SYNODIC PERIOD: In astronomy, the time it takes for a planet or other astronomical object to reappear at the same point in the sky, relative to the position of the sun, is termed the synodic period of that object.

SYNTHESIS: The process of combining simpler chemicals to make a more complex compound.

SYPHILIS: An infectious sexually transmitted disease.

SYSTEMATICS: Field of biology that deals with the diversity of life. Systematics is usually divided into the two areas of phylogenetics and taxonomy.

T

T CELLS: A class of white blood cells distinguished by having the molecule known as the T-cell receptor on their surface. There are seven different varieties of T cell, all with distinct roles in the immune system.

TANGENT: A trigonometric function that represents the ratio of the opposite side of a right triangle to its adjacent side.

TAXONOMY: The science dealing with the identification, naming, and classification of plants and animals.

TECTONICS: In geology, large-scale processes that shape Earth's crust, such as those that build mountains and valleys. Plate tectonics is the theory that explains the large-scale features of Earth in terms of moving plates or rafts of rocky material floating about on the planet's liquid interior.

TELEMETRY: Telemetry is the process of making measurements from a remote location and transmitting those measurements to receiving equipment.

TERABYTE: In computer science, a unit of information, whether stored or transmitted, equal to one trillion bytes. Since each byte equals eight bits, where a bit is a single binary digit, i.e., a 0 or 1, a terabyte is 8 trillion bits.

TETRAVALENT: In chemistry, a tetravalent (four-valent) atom is one that has a valence of 4, that is, four electrons available for covalent (electron-sharing) bonding with other atoms. A tetravalent atom will bind with 4 other atoms; for example, carbon is tetravalent, so in methane, CH_4, it bonds covalently with four hydrogen atoms (which are monovalent).

THEORIES OF EVERYTHING (TOEs): Theories of everything are sought-after systems of physical law that would incorporate both quantum mechanics and general relativity into a single, coherent system of explanations. Presently, these two physical theories work extremely well in their own domains of application, but neither can be extended to all physical conditions.

THEORY: An explanation for some phenomenon that is based on observation, experimentation, and reasoning.

THERAPEUTIC CLONING: A type of cloning that involves somatic cell transfer to produce embryonic stem cells.

THERMOMETER: A device for obtaining temperature by measuring a temperature-dependent property, such as the height of a liquid in a sealed tube, and relating this to a numbered scale based on the rise and fall of the liquid.

THYMUS: The thymus is a lymphoid gland localized between the lungs in the anterior superior mediastinum (in the chest). Its cortex (i.e., external layer) is constituted by lymphatic tissue, with the internal portion containing lymphocytes. The thymus also has a thick reticular structure comprised of groups of granular cells enveloped by epithelial cells, known as Hassall's corpuscles. Much remains to be discovered about the thymus' physiological role and products.

TIME DILATION: When an object is stationary relative to an observer, any time-dependent process (e.g., the running of a clock) takes place at a certain rate as seen by the observer. As described by the theory of special relativity, when the object is made to move at a constant speed in a straight line with respect to the observer, clocks moving with the object are seen by the observer to run faster than when at rest. This slowing of time in moving reference frames, termed time dilation, is a real effect, not an illusion.

TOPOLOGY: A subfield of geometry. In particular, it is the mathematical study of shapes apart from any stretching or deformation that they may undergo.

TRANSCRIPTION: The transfer of genetic information from deoxyribonucleic acid (DNA) to ribonucleic acid (RNA). The process of transcription in prokaryotic cells such as bacteria differs from the process in eukaryotic cells (cells with a true nucleus), but the underlying result of both transcription processes is the same, which is to provide a template for the formation of proteins.

TRANSFER RNA (tRNA): In the molecular factories called ribosomes, where cells manufacture proteins, information is brought from DNA to the ribosome by messenger RNA. The ribosome then manufactures the protein according to the list of amino acids conveyed by the messenger RNA. Transfer RNA is a molecule that assists in this process, transporting one amino acid at a time to the growing chain

of amino acids in the protein being manufactured by the ribosome.

TRANSFORM BOUNDARY: Where two or more tectonic plates (large shell-like areas of rock floating on Earth's mantle, sometimes continental in size) are sliding past each other edge to edge, the boundary between the two plates is termed a transform boundary. Earthquakes often occur along transform boundaries as the plates stick, build up strain, and slip suddenly.

TRANSFORMISM: In biology, the view that existing species have come about through the transformation of earlier living things. The term was once synonymous with evolutionism; today, it is obsolete, and "evolution" refers specifically to the theory of descent with modification as developed by English naturalist Charles Darwin (1809–1882) and greatly advanced by biologists over the last century.

TRANSFUSION: A technique used to replace blood lost during an accident, illness, or surgery.

TRANSISTOR: A solid-state electronic device that is used to control the flow of electricity in electronic equipment. It consists of a small block of semiconductor with at least three electrodes.

TRANSLATION: Translation is the process in which genetic information, carried by messenger RNA (mRNA), directs the synthesis of proteins from amino acids, whereby the primary structure of the protein is determined by the nucleotide sequence in the mRNA. Although there are some important differences between translation in bacteria and translation in eukaryotic cells, the overall process is similar.

TRANSMISSION ELECTRON MICROSCOPES (TEM): Devices that produce a highly magnified view of the structure of very thin samples of material. They do so by passing a beam of electrons through the material, which is then detected on the far side of the sample. Today, transmission electron microscopes are especially used in the examination of samples of metal and other solid materials whose microscopic properties are of interest.

TRANSMUTATION: In biology, changing in form or appearance, usually to a higher form of being. In physics, the conversion of one nuclide into another, as by neutron bombardment in a nuclear reactor. Also, in alchemy, the transformation of a base metal into gold.

TREPANATION: The surgical opening of a hole in the skull.

TRIAGE: The process of allocating limited medical resources in a situation of overwhelming need; life-and-death cases likely to benefit from treatment are the first to be treated.

TRIANGULATION: A means of navigation and direction finding based on the trigonometric principle that, for any triangle, when one side and two angles are known, the other two sides and angle can be calculated.

TRIGONOMETRIC FUNCTION: An angular function that can be described as the ratio of the sides of a right triangle to each other.

TROPHIC LEVEL: In biology, eating or ingestion of other creatures. The trophic level of a species is its place in the food chain; a creature that eats another is at a higher trophic level. For example, a frog is at a higher trophic level than a fly.

TRUE (OR GASEOUS) NEBULA: A large cloud of gas or dust in space.

TURBULENCE: Chaotic, rough flow or mixing in a gas or liquid. It is distinguished from smooth flow, which is called laminar flow because it tends to occur in neatly organized layers with smoothly ordered velocities.

U

ULTRASOUND: A form of energy that consists of waves traveling with frequencies higher than can be heard by humans. Also, a non-invasive diagnostic technique for imaging objects and the human body (often a fetus within a uterus) using ultrasound energy. The high-frequency sound waves produce a two-dimensional image of the body tissue by producing vibrations within it, allowing measurement and detection of abnormalities within the body.

UNCONSCIOUS: The part of the human mind of which one is not conscious, but which is actively involved in emotion, memory, the generation of ideas, and perception.

UNFALSIFIABLE: In the practice of science, a theory or claim is unfalsifiable if there are no reasonably possible conditions under which the theory or claim can be proved false. Claims that are unfalsifiable are not scientific because there is no objective way to check them.

UNIFICATION: In physics, the discovery of a single, consistent theoretical framework for describing phenomena that formerly had to be described by separate theories.

UNIFORM CIRCULAR MOTION: Motion in a perfect circle at a constant speed, thought by the ancient Greeks to be the most perfect form of motion and thus the form most natural for celestial bodies.

UNIFORMITARIANISM: Doctrine of geology promoted by English geologist Charles Lyell (1797–1895), asserting three theories: (1) actualism (uniform processes act throughout Earth's history), (2) gradualism (there is a slow, uniform rate of change throughout Earth's history), and (3) uniformity of state (Earth's conditions have always varied around a single, steady state). Uniformitarianism is often contrasted to catastrophism. Modern geology makes use of elements of both views, acknowledging that change can be drastic or slow, and that while some processes operate steadily over many millions of years, others (such as asteroid impacts) may happen rarely and cause catastrophic, sudden changes when they do.

UNIVERSALITY: The property of some mathematical representations of causal systems that certain overall properties of the system do not depend on its detailed properties.

UPLIFT: The process or result of raising a portion of Earth's crust through different tectonic mechanisms.

UREA: Chemical compound of carbon, hydrogen, nitrogen, and oxygen produced as waste by cells that break down protein or under laboratory conditions.

UTERUS: A pear-shaped, hollow muscular organ in which a fetus develops during pregnancy.

V

VACCINATION: The inoculation, or use of vaccines, to prevent specific diseases within humans and animals by producing an immunity to such diseases. The introduction of weakened or dead viruses or microorganisms into the body to create immunity by the production of specific antibodies.

VACUUM TUBE: A sealed glass tube in which the conduction of electricity takes place through a vacuum or gas.

VALENCE: The tendency of an atom to gain or lose electrons in reacting with other atoms.

VARIABLE (MATHEMATICAL): In mathematics, a quantity that can stand for anywhere from two to an infinite number of specific numerical values. A single specific number is termed a constant; variables vary, constants are constant. Variables are most commonly represented by italicized letters of the Latin alphabet, such as x or y.

VARIANT CREUTZFELDT-JAKOB DISEASE: A fatal degenerative disease of the central nervous system caused not by a living agent but by infectious, malformed proteins called prions. Variant Creutzfeldt-Jakob (vCJD) disease is a variety of Creutzfeldt-Jakob, first described in 1996, that tends to afflict young people and can be transmitted by blood transfusions or by eating the flesh of cattle infected with bovine spongiform encephalopathy ("mad cow disease").

VARIOLATION: Variolation was the pre-modern practice of deliberately infecting a person with smallpox in order to make them immune to a more serious form of the disease. It was dangerous, but did confer immunity on survivors.

VECTOR: Any agent, living or otherwise, that carries and transmits parasites and diseases. Also, an organism or chemical used to transport a gene into a new host cell.

VEGANISM: A lifestyle and/or belief system in which a person refuses to eat or use animal-based products, including meat, dairy products, leather, products tested on animals, etc. Veganism is often based upon ethical, moral, and or spiritual beliefs. Veganism is also a manifestation of concern about the rights of animals or concerns regarding mistreatment and killing of animals used in economic products or for commercial food production. Veganism is a healthful lifestyle choice for some, though it can also be based upon a mixture of scientific and pseudoscientific beliefs about the relationship of diet to human health.

VEIN: Vessel that transports blood to the heart.

VENTRICLE: A lower chamber of the heart from which blood is pumped into the arteries.

VIRTUAL PARTICLE: The Heisenberg uncertainty principle in quantum mechanics, named after its discoverer, German physicist Werner Heisenberg (1901–1976), states that it is impossible to know both the momentum and location of a particle at the same time with perfect precision. One of the consequences of this principle is that particles are permitted to pop into and out of existence for brief periods without violating the conservation of matter. These particles are termed virtual particles to distinguish them from permanent particles. Exchanges of virtual particles mediate the electromagnetic, weak, and strong forces.

VIRULENT: A virus or bacterium that is especially prone to cause infection.

VIRUS: A small, nonliving infectious agent that is a repository of nucleic acid. It consists of a core of

genetic material (either deoxyribonucleic acid [DNA] or ribonucleic acid [RNA]) surrounded by a shell of protein and requires the presence of a living prokaryotic or eukaryotic cell for the replication of the nucleic acid. There are a number of different viruses that challenge the human immune system and that may produce disease in humans.

***VIS VIVA*:** In the late 1600s, German scientist Gottfried Leibniz (1646–1716) proposed a theory of kinetic energy conservation that became known as *vis viva* (Latin for "living force"). The theory is now obsolete; kinetic energy is not, in fact, conserved, though momentum, a closely related quantity, is conserved.

VISCOSITY: The internal friction within a fluid that makes it resist flow.

VITALISM: The concept that compounds found within living organisms are somehow essentially different from those found in nonliving objects.

VITAMIN: A complex organic compound found naturally in plants and animals that the body needs in small amounts for normal growth and activity.

VIVISECTION: The dissection of a living animal. Until the twentieth century, it was practiced without anesthesia, so it was torturous for the subject animal. Vivisection is still practiced in medical research, but ethical guidelines require the anaesthetization of the animal so that the vivisection is painless.

VORTEX: A rotating column of a fluid such as air or water.

W

WAVELENGTH: The distance between one peak or trough of a wave (e.g., light wave) and the next corresponding peak or trough.

WAVE-PARTICLE DUALITY: The combination of wavelike and particle-like properties possessed by all physical objects, which is especially apparent for single subatomic particles such as electrons. Under some conditions, a particle behaves as a small object that can be definitively found in one place or another; under other conditions, a particle behaves as a wave that is spread throughout space and can add or subtract from similar waves in a way that would be impossible for a tiny, hard object that has a single, well-defined location at all times.

WEAK FORCE: In physics, the electroweak force is the single unified force of which the electromagnetic force and weak interaction are both manifestations. The weak interaction is involved in certain types of radioactive decay (e.g., beta decay of neutrons).

WEAK INTERACTION: In physics, the electroweak force is the single unified force of which the electromagnetic force and weak interaction are both manifestations. The weak interaction is involved in certain types of radioactive decay (e.g., beta decay of neutrons).

WHALING: The harvesting of whales for their products by individuals or commercial operations.

WMAP: The WMAP probe (Wilkinson Microwave Anisotropy Probe) is a satellite launched by NASA in 2001 and still operating as of 2008. Its mission was to measure slight variations in different directions (anisotropy) of the cosmic microwave background, a low-level bath of radio waves that is the afterglow of the big bang 13.7 billion years ago. The character of these variations has confirmed the expansion version of the big bang theory, helped pin down the age of the universe with unprecedented precision, helped characterize the amounts of dark matter and dark energy in the universe, and contributed to other advances in cosmology.

WORLD WIDE WEB: A collection of hypertext markup language documents that are linked to each other through the Internet. At least 10 billion (and possibly many more) pages are interlinked to form the World Wide Web, which has developed entirely since 1989.

X

XENOGRAFT: Tissues and organs used for transplantation that come from different animal species, like pigs or baboons.

Y

YEAST: A microorganism of the fungus family that promotes alcoholic fermentation and is also used as a leavening (fermentation) agent in baking.

YELLOW BILE: The ancient Greek and Roman theory of physiology stated that four basic substances, the humors, exist in the human body, and that disease is caused by an imbalance among the humors. The four humors were blood, phlegm, yellow bile, and black bile; an excess of yellow bile was believed to cause an angry, vindictive disposition.

Z

ZENO'S PARADOXES: A set of logical puzzles invented by the Greek philosopher Zeno (c.490–430 BC) that examines the nature of motion and appears to show that ordinary motions are impossible. The most famous is Zeno's apparent proof that a fast runner cannot overtake a slow tortoise: during every period of time, as the runner advances, the turtle advances too (though not as far), and it is apparently contradicted by logic that the runner should ever catch up. Today, we recognize that such a conclusion is false because an infinite series of finite numbers can add up to a finite sum. In this case, the infinite series of diminishing gains made by the tortoise add up to a finite number: The runner does indeed catch up to the tortoise in finite time and then pass it.

ZODIAC: In astrology, a strip or band of the visible heavens encircling Earth. It is centered on the ecliptic, which is that line in the sky along which the sun moves. The Zodiac is divided up into sectors named after various constellations (patterns of stars).

Chronology

A chronology of events related to the history of scientific thought.

BC

c.4600000000 BC
Origin of Earth: 4,600 billion years ago.

c.50000 BC
Homo sapiens sapiens emerges as a conscious observer of nature.

c.30000 BC
Stone Age cultures use pigments to color various artifacts.

c.10000 BC
Neolithic Revolution: transition from a hunting and gathering mode of food production to farming and animal husbandry, that is, the domestication of plants and animals.

c.9000 BC
The Mayan tribes in Central America make astronomical inscriptions and constructions. These Indian people (now Yucatan, northern Guatemala, and British Honduras) prepare planetary tables and pay special attention to Venus, upon whose movements their system of timekeeping is based.

c.8000 BC
Pebbles are painted with geometric symbols in area near present day Mas d'Azil in France.

c.8000 BC
The first forms of fired clay are used by Neolithic people to keep track of agricultural products. They are unmarked and have geometric shapes.

c.6500 BC
Bones with markings are used near present day Zaire to record months in terms of phases of the moon.

c.6000 BC
The rise of the great ancient civilizations, beginning 6,000 years ago in Mesopotamia, begat institutions and persons devoted to the collection and teaching of agricultural science and technology to support infrastructure.

c.6000 BC
Earliest example of a notched or tally stick is the Ishango bone found on the shore of Lake Edward in Zaire (Congo) and dated to this time. It is believed that this small, notched bone with a piece of quartz stuck in one end is a possible record of some activity based on the lunar cycle.

c.6000 BC
Wine-making begins in northern Mesopotamia and in the Levant (along the eastern Mediterranean shore).

c.4700 BC

Astronomical calendar stones are used on the Nabta plateau in Egypt. Megaliths mark the position of star locations (e.g. where stars "rise" on the horizon) at the solstice.

c.4000 BC

The Egyptian calendar based on 365 days is established. Because the Egyptian economy depends on the annual flooding of the Nile River, it is essential to know the onset of flooding season. When the priests see Sirius, the brightest star in the sky, rising in line with the sun in the morning, they know that this date usually coincides with the yearly flood.

c.4000 BC

Early applied chemistry begins with the extraction and working of metals and the manufacture of pottery. Objects made of cast copper appear with the early tribes and civilizations of Egypt and Mesopotamia.

c.3500 BC

Early sundials are employed by the Egyptians, who use some sort of pillar to cast a shadow but do not use it with a dial that has markings.

c.3500 BC

The Egyptian number system reaches the point where large numbers can be recorded by introducing new symbols.

c.3500 BC

The Sumerians develop a type of pictographic writing that will eventually evolve into cuneiform. The pictographs are marked in horizontal strips on baked clay tablets.

c.3500 BC

Earliest illustration of a sail dates from this period. It is painted on the outside of a funerary vase found near Luxor, Egypt. The sail is fixed to a single mast, and there is a shelter aft or toward the rear.

c.3500 BC

Jugs crafted by ancient civilizations to hold beer and wine are used. Alcohol is used as disinfectant, medicinal remedy, and to reward soldiers.

c.3400 BC

Bronze, an alloy of copper and tin, first appears in abundance in Sumeria. The Sumerians become expert in the working of gold, silver, copper, lead, and antimony.

c.3100 BC

Traders in the Mesopotamian city of Uruk begin to use symbols for abstract numbers.

c.3000 BC

Assyrians develop sewer network to carry waste water.

c.3000 BC

Papyrus is used in Egypt for writing.

c.3000 BC

Sumerian clay tokens become standardized and begin to represent different numerals.

c.3000 BC

The construction of the Egyptian pyramids at Giza begins. The fact that they are oriented to the cardinal points of the compass and that their interiors have inclined passages that point to the pole star of the period are strong evidence that the Egyptians possessed precise sighting or astronomical instruments.

c.3000 BC

The Sumerians in the lower Euphrates valleys build dams, canals, statues, and pyramids, demonstrating a working knowledge of the lever and other basic tools.

c.3000 BC

Egyptian papyri contain references to inflammation, pus, and abscesses.

c.2950 BC

Imhotep, Egyptian scholar, is the architect of the "step pyramid" at the ancient site of Memphis. As the first of the pyramids, it is 200 feet (61 m) high with a base 388 feet (118 m) by 411 feet (125 m). Its successful completion evidences the ability of ancient engineers and their familiarity with the basics of mechanics.

c.2900 BC

Chinese Emperor Fu-Hsi (the first of China's mythical emperors) invents the principles of yin and yang, which become the basis of ancient Chinese medicine.

c.2900 BC

Stonehenge is begun on the Salisbury Plain in England. This early version consists of an earthen bank and a ditch along 56 holes.

c.2700 BC

Acupuncture is invented by the Chinese Emperor Shen-Nung (the second of China's mythical emperors) who also writes the *Pen-Tsao,* considered the first medical herbal text.

c.2700 BC

Cuneiform signs and numerals on Sumerian tablets use a slanted double wedge as a placeholder between number symbols to indicate the absence of a number, or zero, in a specific place.

c.2637 BC

Earliest recorded reference to the use of magnetic influence is made in China during the reign of emperor Hoang-ti. Reference is made to the use of a directional needle during wartime.

c.2600 BC

What is later known as the Smith papyrus records medical diagnosis and treatment of the era.

c.2600 BC

The Chinese make a primitive sundial and estimate the time of day by using a rod placed in the ground to project the sun's shadow.

c.2600 BC

The Great Pyramid at Giza near present-day Cairo, Egypt, is erected. Covering 13 acres and containing over 2 million stone blocks, it is a testament to the impressive mathematical and engineering skills of the Egyptians.

c.2600 BC

Chinese Emperor Huang-ti (the third of China's mythical emperors) writes the *Neiching*, a standard Chinese text on internal diseases.

c.2500 BC

Chinese astronomers record a grouping of bright planets that occurs around this time.

c.2500 BC

Surgical operations are depicted on the tomb of the Pharaohs at Saqquarah (part of the ancient city of Memphis, southwest of Cairo, Egypt).

c.2400 BC

Positional notation comes into use in Mesopotamia by the Sumerians. It has a base of 60 instead of 10 and uses cuneiform symbols.

c.2300 BC

The oldest surviving map of a city is a carved stone map of the Mesopotamian city of Lagash.

c.2300 BC

Proto-Indian writing is used in the Indus Valley.

2296 BC

Earliest recorded sighting of a comet is made by Chinese astronomers.

c.2200 BC

Many mathematical tablets found at Nippur, a city of ancient Sumer in Babylonia, are dated to this time.

c.2100 BC

The Babylonians modify their calendar to allow for the movement of the stars. They add an extra month to compensate for the revolutions of the heavenly bodies.

c.2000 BC

Physicians organize into scholarly and professional groups in the Middle East.

c.2000 BC

Babylonians regularly use the rules of mensuration or measuring.

c.2000 BC

Mathematicians in Mesopotamia learn to solve quadratic equations or equations in which the highest power is two.

c.1850 BC

The Moscow or Golenishev papyrus, dated to this period, shows that the Egyptians know cipherization and possess a considerable knowledge of geometry. Along with the Rhind papyrus, this becomes a major source of information about Egyptian mathematics.

c.1800 BC

By this time, a well developed additive number system was in use in Egypt.

c.1800 BC

Medical practice in the Babylonian Empire is governed by the Code of Hammurabi.

c.1800 BC

Male flower of the date plant is mentioned in a Babylonian document. Even though scientists did not experimentally

demonstrate plant sexuality until the seventeenth century, in ancient Mesopotamia, the date palm was cross-pollinated and the ratio of male to female trees was regulated in order to secure good crops.

c.1800 BC

Egyptian papyrus lists many diagnoses of head and neck trauma and remedial therapies. The papyrus is also significant because it is one of the first indicators that ancient physicians understood that the brain played a fundamental role in controlling the body.

c.1775 BC

Babylonian astronomers, under their king Hammurabi, compile star catalogs, planetary records, and the famous Venus Tablet.

c.1700 BC

Rhind papyrus shows use of mathematical formula including pi.

c.1700 BC

The peoples of Syria-Palestine develop the first real alphabet, which is later transmitted by the Phoenicians to the Greeks in the tenth century BC.

c.1600 BC

Chaldean astrologers identify the zodiac or constellation patterns. They are a Semitic tribe that live in an area near the Euphrates River and Persian Gulf.

c.1580 BC

The oldest surviving papyrus of any length, the Egyptian "Book of the Dead," is dated to this time. This collection of mortuary texts is composed of spells and magic formulas and is placed in tombs to protect the dead. This is considered by some scholars to be the first "book."

c.1500 BC

Between 1500 BC and 1200 BC Greece's many wars with its regional rivals led to the development of new military technology.

c.1500 BC

Rig-Veda in the Indian Vedas, a collection of religious, philosophical, and educational writings, states that Earth is a globe.

c.1500 BC

Yajur-Veda in the Indian Vedas, a collection of religious, philosophical, and educational writings, states that Earth circles the sun.

c.1500 BC

Vedic medicine in India first begins.

c.1500 BC

Stone tablets found at Nippur (Iraq) in the 1930s by Otto Neugebauer (1899–1990) suggest that the Babylonians are using the abacus at this time—some of the pictographs are reminiscent of the form of an abacus.

c.1500 BC

Babylonian mathematicians demonstrate use of the determination of the diagonal of a square using a method later known in the Pythagorean theorem.

c.1475 BC

Thutmose III (c.1501–c.1425 BC), Egyptian pharaoh, erects the obelisk called "Cleopatra's Needle" in Heliopolis (modern Cairo). Its shadow is used to calculate time, seasons, and solstices. It eventually is transported to London in the nineteenth century.

c.1400 BC

The Olmec people on the east coast of Mexico develop a numeration system and calendar as well as the beginnings of a written language. These are eventually adopted by the Mayans and the Zapotec.

c.1400 BC

Ugaritic tablets contain first known alphabetic writing, utilizing thirty cuneiform signs.

1352 BC

When Egyptian King Tutankhamen dies this year, he is buried with his chariots. When the intact tomb is discovered in 1922 by English archaeologist Howard Carter (1873–1939), working parts of dismantled wooden chariots are found. The chariot was introduced to Egypt around 1600 BC by Asiatic invaders, the Hyksos.

c.1350 BC

The Chinese use decimal numerals.

c.1200 BC

Iron smelting is performed in West Africa.

c.1200 BC

Mohammed Ben Mansur classifies stones according to their hardness and specific gravity.

1110 BC

Reference is made to ambassadors from Cochinchina (Vietnam) being given a compass on their departure from China.

c.1105 BC

The *Chou-pei* is written and is the oldest extant Chinese mathematical work. It indicates that the Chinese know of the Pythagorean theorem of the right triangle.

c.1100 BC

The rotary or true quern for grinding grain appears in the Mediterranean area. It uses a handle that rotates one stone atop a stationary stone. It is the precursor of the heavy querns used later by the Greeks and Romans that are operated by slaves or donkeys.

c.1000 BC

Hindu physicians exhibit broad clinical knowledge of tuberculosis. In India, the Laws of Manu consider it to be an unclean, incurable disease and an impediment to marriage.

c.1000 BC

Beginning of Greek metallurgy; the Greeks use iron.

c.900 BC

Homer, Greek epic poet, refers to the use of a lodestone for navigation purposes during the siege of Troy.

c.763 BC

Earliest recorded solar eclipse is observed by Babylonian astronomers.

c.720 BC

An eclipse of the moon is observed at Babylon and is later recorded by Greek astronomer Ptolemy (AD c.91–c.168).

c.720 BC

Chinese record-keeping of solar eclipses begins this year.

c.700 BC

Atharva-Veda, the famous Indian medical text, is written.

c.700 BC

Greek soldiers wear plate armor made of bronze and iron to protect the torso.

c.700 BC

Sennacherib, king of Assyria, builds aqueducts to carry water into the city of Ninevah, as does Hezekiah, king of Judah, to supply Jerusalem with water.

c.700 BC

The Persians adopt the cuneiform system of writing and adapt it to their Indo-European language. They begin to approach the development of an alphabet.

c.700 BC

The use of anatomical models is established in India.

c.700 BC

Greeks demonstrate force of electric attraction produced by rubbing amber.

c.630 BC

Mimnermus of Colophon, Greek elegiac poet, records the myth that the sun, after setting, is carried around Earth in a golden bowl until it is brought into view again the next morning in the east.

c.609 BC

First circumnavigation of Africa is begun by the order of Egyptian Pharaoh Necho II. He commissions a Phoenician fleet and orders its captains to sail from Suez indefinitely, always keeping land within sight on the starboard (right) side. Four years later, the fleet arrives in Alexandria, having gone completely around Africa and returned to the Mediterranean via the Straits of Gibraltar.

c.604 BC

Nebuchadnezzar, king of Babylon, erects a seven-story tower in Borsippa, a suburb of Babylon, as some sort of astronomical monument. It is believed to symbolize the seven celestial bodies then known.

c.600 BC

Thales of Miletus (624–546 BC), Greek philosopher, writes one of the earliest treatises on physics and proposes that water is the fundamental element from which everything is made. He also writes the first known geological observation, describing the effect of streams. He is also the first to systematically study magnetism.

c.600 BC

The abacus is known to be in use in Greece at this time. Referred to as a sand tray, this early mechanical computing device uses vertical columns and counters.

c.600 BC

Anaximander, Greek astronomer, describes the ecliptic plane and asserts that Earth's surface assumes a curved, cylindrical shape.

c.585 BC

An eclipse of the sun occurs, an event that was correctly predicted earlier in this year by the Greek philosopher Thales of Miletus. He also maintains correctly that the moon shines at night by reflected sunlight.

c.585 BC

Thales of Miletus, Greek philosopher, converts Egyptian geometry into an abstract study. He removes mathematics from a sole consideration of practical or concrete problems and goes about proving mathematical statements by a regular series of logical arguments. Doing this, he invents deductive mathematics. He is also credited with discovering several geometrical theorems.

c.570 BC

Anaximander (610–c.546 BC), Greek philosopher, contributes the first notion of spheres to the study of astronomy. He recognizes that the heavens revolve around the Pole Star and therefore pictures the sky as a complete sphere rather than as an arch over Earth. He also says that space is three-dimensional.

c.568 BC

A Babylonian tablet made in this year shows the different positions of the planets in relation to the constellations.

c.550 BC

Anaximander (610–c.546 BC), Greek philosopher, is the first known person to study fossils. He also is the first to draw a map of the entire Earth as he knows it. He states that life originated in the water, and that humans developed from fish.

c.550 BC

Anaximander (610–c.546 BC) draws the first known map of the inhabited earth and puts the map on a cylinder to show that Earth's surface is curved.

c.550 BC

Cyrus II the Great of Persia (c.590–c.529 BC) connects his empire using relays of mounted messengers served by posthouses.

c.550 BC

Pythagoras (c.582–c.497 BC), Greek philosopher, studies sound with experiments on the monochord. Pythagoras discovers the relation of musical intervals on the arithmetical ratios of the lengths of string at the same tension, 2:1 yielding an octave, 3:2 a fifth, and 4:3 a fourth.

c.550 BC

Pythagoras (c.582–c.497 BC), Greek philosopher and mathematician, advances studies of geometry and geometric form. Pythagoras asserts Earth is a sphere.

c.540 BC

What many believe may have been the first public library is founded at Athens by the Greek dictator Pisistratus (600–527 BC).

c.532 BC

Theodoros of Samos, Greek architect and engineer, invents the carpenter's square and the bubble level.

c.530 BC

Pythagoras (c.582–c.497 BC), Greek philosopher, is the first to recognize that the morning star (Phosphorus) and the evening star (Hesperus) are in fact the same star. We know it today as the planet Venus. He is the first to point out that the sun, moon, and various planets do not move uniformly like the stars, but that each has its own orbital path.

c.530 BC

Pythagoras (c.582–c.497 BC) advances formula for finding two square numbers the sum of which is also a square.

c.530 BC

Pythagoreans develop the theory of geometric magnitudes, enabling them to compare surface ratios.

c.523 BC

A text produced this year during the reign of Cambyses II, King of Persia, calculates the future positions of the moon and sun in relation to each other. It also calculates the positions of the planets in the zodiac.

c.522 BC

Democedes, Greek physician, founds a medical school at Athens.

c.500 BC

Brahmanic medicine first begins in India.

c.500 BC

First known dissection of the human body is performed by the Greek physician, philosopher, and naturalist Alcmaeon.

c.500 BC

Heraclitus (c.540–475 BC), Greek philosopher, states that fire is the fundamental element of the universe. He also states that all things are in constant motion, and that nothing is ever lost.

c.500 BC

Pythagoras (c.582–c.497 BC), Greek philosopher, formulates the idea that the entire universe rests on numbers and their relationships. To him or his school are attributed several mathematical principles and discoveries (such as being the first to work out by strict mathematical deduction that the square of the length of the hypotenuse of a right triangle is equal to the sum of the squares of the lengths of its sides).

c.500 BC

Rotary mills driven by donkeys appear in the Mediterranean world.

c.500 BC

Silver coins are introduced for the first time at Aegina and Corinth as an economy based on coin money begins to develop.

c.500 BC

Xenophanes (c.570–c.480 BC), Greek philosopher, attributes seashells on mountain tops to the fact that the mountains must have been covered by the sea at some time. He argues that the physical characteristics of Earth change over time and that earth is the fundamental element of the universe.

c.500 BC

Hippasus, Greek mathematician, constructs the circumscribed sphere called a dodecahedron, a regular solid with twelve pentagon faces.

c.500 BC

Pythagoras (c.582–c.497 BC), Greek philosopher, suggests that the brain is the organ of the mind. This idea contradicts established notions, which say that the heart or the liver is the seat of intelligence, and that the brain serves only to cool the body.

c.500 BC

Alcmaeon, Pythagorean physician, philosopher, and naturalist, pursues anatomical research and concludes that humans are fundamentally different from animals. He also differentiates arteries from veins. His work establishes the foundations of comparative anatomy.

c.480 BC

Demaratus of Sparta uses an early form of secret writing, concealing a message on a wooden tablet covered with wax, to warn his countryman of invasion by the Persian empire.

c.480 BC

Oenopides of Chios calculates angle of Earth's polar axial tilt to ecliptic.

c.480 BC

Parmenides of Elea founds the Eleatic School, which asserts that to arrive at a true statement, logical argument is necessary.

c.480 BC

The Greek number system (the later developed Roman system), does not use the Babylonian positional number system and the Babylonian marker for "nothing."

c.462 BC

Anaxagoras (c.500–c.428 BC), Greek philosopher, states that metals grow in the crust of Earth.

c.455 BC

Philolaus (c.480–c.385 BC), Greek philosopher, argues that night and day are caused by Earth's rotation.

c.450 BC

First known reference to the use of the symbol for zero is made in India.

c.450 BC

Butter is known to be used by the Scythians, who inhabit the country near the Black Sea and the Caspian Sea.

c.450 BC

Empedocles (c.492–c.432 BC), Greek philosopher, first offers his concept of the composition of matter being made of four elements—earth, air, fire, and water. This notion is adapted by Aristotle (384–322 BC)

and becomes the basis of chemical theory for over two thousand years.

c.450 BC

Leucippus, Greek philosopher, first states the rule of causality (every event has a natural cause). He is also the teacher of Democritus (c.470–c.380) and the supposed inventor of that philosopher's theory of atomism.

c.450 BC

Zeno (c.490–c.425 BC), Greek philosopher, offers his four paradoxes of motion. All are fallacies, based on the assumption that space and time are infinitely divisible and that sensory information should be ignored, but they are extremely important as they stimulate mathematical thought.

c.450 BC

Philolaus (c.480–c.385 BC), Greek philosopher and mystic, is the first to state that Earth moves through space.

c.450 BC

The Greek philosopher Leucippus first states the notion of atomism. He argues that upon continuous division of a substance, eventually a point would be reached beyond which further division was impossible. His disciple, the Greek philosopher Democritus (c.470–c.380 BC), ultimately names these small particles *atomos*, meaning indivisible.

c.450 BC

Anaxagoras (c.500–c.428 BC), Greek philosopher, offers one of the first atomic theories, saying that all matter consists of atoms or "seeds of life."

c.450 BC

Anaxagoras (c.500–c.428 BC) of Athens teaches that the moon shines with the light of the sun.

c.440 BC

Oenopides, Greek astronomer and mathematician, calculates the angle of Earth's axis of rotation (to a line perpendicular to its plane of revolution about the sun) at about 24 degrees. This is only one-half degree larger than its correct value.

c.440 BC

Hippocrates of Cos (460–370 BC), Greek geometer, writes his *Elements*, the first known textbook on geometry. He arranges the known propositions of geometry in a scientific fashion, and his work may have served as a model for Euclid's *Elements*.

c.440 BC

Oenopides of Chios is credited with contributing the first three of what became Euclid's geometric postulates.

c.440 BC

Protagoras of Abdera asserts that man only knows what he perceives, not the actual thing perceived.

432 BC

Meton, Greek astronomer, discovers that 235 lunar months make up just about 19 years. Using this, he calculates that if one were to arrange to have 12 years of 12 lunar months and 7 years of 13 lunar months, such a lunar calendar would have months to match the seasons. This comes to be known as the Metonic cycle. It serves as the basis of all calendars until Julius Caesar (100–44 BC) establishes the Julian calendar.

c.430 BC

Antiphon, Greek philosopher, offers what becomes called his method of exhaustion as a way of squaring the circle.

c.430 BC

Plague of Athens is caused by unknown infectious agent. One third of the population (increased by those fleeing the Spartan army) dies.

c.425 BC

Democritus (c.470–c.380 BC), Greek philosopher, states his atomic theory that all matter consists of infinitesimally tiny particles that are indivisible. These atoms are eternal and unchangeable, although they can differ in their properties. They can also recombine to form new patterns. His intuitive ideas contain much that is found in modern theories of the structure of matter.

c.425 BC

Herodotus formulates arguments that approximate modern scientific methodology.

c.420 BC

Democritus of Abdera (c.470–c.380 BC) advances the argument that "thought"

is situated in the brain. Socrates, and eventually the Platonic school, concur with Democritus' position.

c.410 BC

Philolaus (c.480–c.385 BC), Greek philosopher, suggests that the sun, moon, and all the planets circle in separate spheres around a central fire; the sun we see is only a reflection of this fire. His theory also contains the first notion that Earth moves through space.

c.400 BC

Aristotle (384–322 BC), Greek philosopher and naturalist, classifies animals into species and classes.

c.400 BC

Archytas, Greek mathematician and philosopher, is the first Greek mathematician to apply mathematics to mechanics. He distinguishes harmonic from geometrical and arithmetical progressions and contributes to a theory of acoustics.

c.400 BC

Hippocrates of Cos (460–370 BC), Greek physician, and his disciples found their medical practice based on reason and experiment. They attribute disease to natural causes and use diet and medication to restore the body's balance of humours.

c.400 BC

Mo-tzu (c.470–c.391 BC), Chinese philosopher also called Mo ti, observes that the reflected light rays of an illuminated object passing through a pinhole into a darkened enclosure result in an inverted but otherwise exact image of the object. This may be the earliest account of what will come to be called the "camera obscura."

c.400 BC

Plato (c.427–c.347 BC), Greek philosopher, theorizes that the heavens exhibit perfect geometric form, and that the various heavenly bodies therefore must move in perfect or exact circles.

c.400 BC

Hippocrates (460–c.370 BC), Greek physician, writes his text on reproduction, "On the Seed." He also states that mumps can be followed by orchitis and sterility.

c.400 BC

The Spartans employ a cipher device called the *scytale* to ensure secure communications between their commanders. This is the first recorded use of cryptography in the field of communications.

c.400 BC

Democritus (c.470–c.380 BC) advocates preformation theory of generation (embryology).

c.400 BC

Hippocrates (460–370 BC) suggests using the developing chick egg as a model for embryology and notes that offspring inherit traits from both parents.

c.400 BC

Babylonian astronomers formalize prediction of moon phases and the occurrence of lunar eclipses.

c.400 BC

Hippocrates (460–370 BC) argues that diseases have natural causes. The "Hippocratic method" of treatment of the sick emphasized rest and self healing.

397 BC

Stone and javelin-throwing machines are used by the Greeks against the Carthaginians.

c.380 BC

Plato (c.427–c.347 BC), Greek philosopher, presents his philosophy of mathematics. He holds that nature is pervaded by mathematical harmony and mathematical structure, and that a knowledge of mathematics is essential if the mind is to be trained properly. Platonism in science has come to mean an emphasis on a priori, abstract mathematical thinking.

c.380 BC

Plato (c.427–c.347 BC) teaches a geometrical theory of matter on which he elaborates in his *Timaeus*.

c.375 BC

Theaetetus (c.417–c.369 BC), Greek mathematician, systematizes the study of irrational numbers and shows that they exist in large numbers.

c.370 BC

Eudoxus of Cnidus (c.408–c.355 BC), Greek astronomer and mathematician, introduces mathematics into astronomy and creates the general theory of proportion later used by Euclid. He also solves several difficult geometrical problems.

c.360 BC

Eudoxus of Cnidus (c.408–c.355 BC), Greek philosopher, corrects faults in Plato's planetary orbital scheme (e.g., that the sun, planets, and stars orbit Earth on celestial spheres).

c.350 BC

Aristotle (384–322 BC) offers his doctrine of the elements, stating that all things are composed of a basic material in combination with the four qualities—hotness, dryness, coldness, and wetness. This theory eventually suggests the idea of transmutation (the changing of ordinary metals into gold or silver) and gives rise to alchemy.

c.350 BC

Aristotle (384–322 BC) offers observational proofs that Earth is not flat.

c.350 BC

Aristotle (384–322 BC) rejects the atomism of the Greek philosopher Democritus (c.470–c.380 BC), thus condemning it to be forgotten through medieval times. He also states that a vacuum does not exist in nature, and that sound travels by a succession of impacts on the air. He argues correctly that sound is not conducted in the absence of air and incorrectly that a body will move only as long as it is pushed. He also says that heavy bodies fall faster than light ones.

350 BC

Heracleides (c.388–315 BC), Greek astronomer, is the first to suggest the idea of the rotation of Earth. Although he incorrectly places Earth in the center of the universe, he nonetheless is also the first to suggest that one heavenly body can revolve around another. He also explains the daily movement of the fixed stars by the rotation of Earth.

c.350 BC

Praxagoras, Greek physician, first distinguishes between veins and arteries, recognizing that there were two different kinds of blood vessels.

c.350 BC

Aristotle (384–322 BC) writes on the topic of sperm, saying that semen is the formative or activating agent, with the female element being the passive "soil" to be fertilized. He also states that the right testicle produces boys and the left, girls. He knows of the effects of castration and its use in husbandry.

c.350 BC

Dinostratus, Greek mathematician and brother of Menaechmus, contributes to calculating the area of a circle and attempts to square the circle.

c.335 BC

Eudemus of Rhodes, Greek mathematician, writes an early history of geometry.

c.335 BC

Aristotle (384–322 BC) defines a syllogism as a formal argument in which the conclusion must follow from the premises.

c.325 BC

Pytheas argues that tides are caused by motions of the moon.

c.323 BC

Theophrastus (c.372–c.287 BC), Greek botanist and head of the Peripatetic school of philosophy, in his *Historia Plantarum* and *De Causis Plantarum* classifies parts of plants and of flowers and describes processes of fertilization.

c.320 BC

Callippus (c.370–c.300 BC), Greek astronomer, refines the mathematical planetary theory of his teacher, Eudoxus (c.408–c.355 BC). He also measures the length of the seasons accurately.

c.300 BC

A medical school is set up in Alexandria where the first accurate anatomical observations using dissection are made. The principal exponents of the school are Greek anatomist and physician Herophilus (c.335–c.280 BC) and Greek physician Erasistratus of Chios (c.304–c.250 BC).

c.300 BC

Demetrius Phalereus (c.350–c.280 BC), Greek philosopher and governor of Athens, begins the practice of collecting copies of all

known books to stock the pharaoh's library. At the height of Alexandrian culture, the two royal libraries contain between 500,000 and 750,000 books on papyrus scrolls.

c.300 BC

Dicaearchus (c.355–c.285 BC), Greek geographer, is the first to draw a line of latitude from east to west across a map, noting the fact that all points on that line saw the noonday sun (on any given day) at an equal angle from the zenith.

c.300 BC

Herophilus (335–280 BC) describes the ovaries, which he calls the "female testicles."

c.300 BC

Herophilus (335–280 BC) sees the brain as the primary organ of the nervous system. He also correctly associates nerves with movement and sensation.

c.300 BC

Herophilus (335–280 BC) establishes himself as the first systemic anatomist and the first to perform human dissections.

c.300 BC

Kiddinu, Babylonian astronomer, devises a complicated method of expressing the irregular movements of the moon and other planetary bodies and departs from the Greeks' incorrect notion that they all must move at constant velocities.

c.300 BC

Manual on the art of politics, *Artha-sastra*, is written in India. It also contains details on mining, metallurgy, medicine, pyrotechnics, poisons, and fermented liquors.

c.300 BC

The astrolabe is used by Greek astronomers to observe the positions and altitudes of celestial bodies. In its early form, it consists of a wooden disk, marked with degrees, that is suspended by a ring.

c.300 BC

Theophrastus (371–c.287 BC) writes a treatise on mineralogy in which he identifies and names many rocks and minerals. Some names are still used.

c.300 BC

Euclid (c.325–c.270 BC), Greek mathematician, writes a textbook on geometry called the *Elements* that becomes the standard work on its subject for over 2,000 years. Although not an original work, it codifies into a single book all the known mathematical work to its time. It also uses a logically- arranged method of axioms and postulates that are both elegant and simple. Until the nineteenth century, its axioms are taken as absolute truths.

c.300 BC

Herophilus (335–280 BC) studies the circulatory system; his investigation of the nervous system prompts him to identify the brain as the organ of thought.

c.300 BC

A symbol is used by the Babylonians to indicate a gap between numbers, an early form of positional notation, and use a symbol for zero.

c.300 BC

Aristarchus of Samos (c.320–c.250 BC) argues that Earth revolves around the sun.

c.300 BC

Euclid (c.325–c.270 BC) writes a treatise on optics in which he makes optics a part of geometry by dealing with light rays as though they are straight lines. He also offers a theory of reflection, which he treats geometrically.

c.300 BC

Strato (c.340–c.270 BC), Greek physicist, is the first to argue that a body accelerates when falling. He agrees with Aristotle that heavier bodies fall faster than light ones.

c.300 BC

Epicureans advance the view that the development of the world is a random, unidirectional process.

c.275 BC

Erasistratus of Chios (304–250 BC) describes the brain's main parts as well as the meninges and ventricles. He guesses that the brain's convolutions hold the key to intelligence.

260 BC

Aristarchus of Samos (c.320–c.250 BC), Greek astronomer, argues for a sun-centered (heliocentric) cosmology, correctly placing the sun at the center of the universe with the planets revolving around it. This heliocentric theory combines the

Pythagorean idea of a moving Earth with the notion of Heracleides (c.388–315 BC) that some planets move about the sun. His theory is rejected in his own time and is not put forth again until 1543, when Nicolaus Copernicus (1473–1543), Polish astronomer, publishes his revolutionary work.

c.260 BC

Archimedes of Syracuse (c.287–212 BC) uses deduction and experimental verification to advance understanding of fluid statics and dynamics.

c.250 BC

Aratus (c.315–c.245 BC), Greek poet, writes his poem on astronomy called *Phaenomena*. The poem becomes very popular and is regularly commented on by astronomers through Roman times and into the Middle Ages.

c.250 BC

Archimedes (c.287–212 BC), Greek mathematician and engineer, invents the Archimedean screw for raising water. This hollow, helical cylinder can scoop up water from a lake or pond and deliver it to a higher level when it is rotated.

c.250 BC

Asoka (272–232 BC), king of the Maurya empire in India, erects stone pillars in several major cities that contain the earliest preserved representation of the number symbols we use today.

c.250 BC

The Maya (of Central America and Southern Mexico) develop a number system based on 20, which also possesses a zero. Their numbers are written vertically.

c.250 BC

Philon, Greek engineer, experiments with air and discovers that it expands with heat.

c.250 BC

Chinese philosophers argue that free bodies move at constant velocity.

240 BC

Chinese astronomers make the first recorded observation of what comes to be known as Halley's Comet.

c.240 BC

Eratosthenes (c.276–c.196 BC), Greek astronomer, makes a map of the known world and is the first to estimate correctly the size of Earth. Knowing that on the summer solstice, the sun is directly overhead in Cyrene, and at the same time seven degrees from zenith in Alexandria, he guesses that the difference can only be due to the curvature of Earth. His circumference calculation of about 25,000 miles is almost correct.

c.240 BC

The Sieve of Eratosthenes is used to determine prime numbers.

c.240 BC

Astrolabes are used to determine the angular distance between two objects. In astronomy they are used to determine elevations (the elevation of a planet above the horizon).

c.240 BC

Diocles (c.240–c.180 BC), in *On Burning Mirrors* demonstrates the focal properties of a parabolic mirror (e.g., showing show the sun's rays can be focused).

c.230 BC

Archimedes (c.287–212 BC) observes solstices and attempts to measure the sun's diameter.

c.225 BC

Apollonius (c.262–c.190 BC), Greek mathematician, attempts to reconcile differing planetary theories by claiming that the planets revolve around the sun, and that the sun, with its planets, then revolves around Earth.

c.220 BC

Archimedes writes his *Treatise on Floating Bodies*, in which he relates the principle of buoyancy.

c.140 BC

Hipparchus (c.190–c.120 BC), Greek astronomer, founds trigonometry. In his calculations to measure the size and distance of the sun and moon, he works out an accurate table of chords or trigonometric sections.

134 BC

Hipparchus (c.190–c.120 BC), makes the first accurate, systematic star map. He is also the first to divide stars into classes depending on their brightness. The twenty bright-

est stars are of "first magnitude," while those of the sixth magnitude are just visible to the naked eye. The essentials of this system remain in use in the modern era.

c.60 BC
Lucretius (c.95–c.55 BC), Roman philosopher, describes how to create the illusion of motion by a fast, sequential display of individual pictures.

52 BC Ken Shou-Ch'ang, Chinese astronomer, builds an armillary sphere of metal that is used in observing stars.

c.50 BC
Sosigenes, Greek astronomer, suggests a new calendar consisting of a 365-day year three times in a row to be followed by a 366-day leap year. This system is adopted by Julius Caesar (100–44 BC) in 46 BC and has lasted until today.

c.50 BC
Lucretius (c.94–c.50 BC) proposes a materialistic, atomistic theory of nature in his poem *On the Nature of Things*. He favors the preformation theory of embryological development.

40 BC Strabo (c.6 BC–AD 24) publishes his *Geographia*.

c.30 BC
Diodorus of Sicily (c.90–c.30 BC), Greek historian, describes volcanoes in his encyclopedic history.

29 BC Virgil (70–19 BC), Roman poet whose full name is Publius Vergilius Maro, finishes his long didactic poem called *Georgica* or the "Georgics." This is the best known of the ancient works on agriculture and deals with all aspects of husbandry and farming.

c.20 BC
Strabo (c.63 BC–AD 19), Greek geographer, suggests the existence of unknown continents, recognizes the long-dormant Vesuvius as a volcano, and discusses the land-forming activity of rivers.

AD

c.25 Pomponius Mela, Roman geographer, publishes *De situ orbis*, which includes a map of the known world. His writings formalize the notion of climatic latitudes.

c.30 Aulus Cornelius Celsus (c.25–c.50), Roman encyclopedist, writes his influential book *De Re Medicina* (On Medicine). This work contains good descriptions of many conditions and operations and is probably drawn mostly from the collection of writings of the school of Hippocrates (460–370 BC). It is rediscovered during the fifteenth century and becomes highly influential.

c.35 Marcus Gavius Apicius, Roman epicure, writes what many consider to be the oldest cookbook. Titled *De Re Coquinaria*, it contains glimpses of Roman cooking and eating habits as well as recipes.

c.44 Pomponius Mela, Roman geographer, divides Earth into five zones (North Frigid, North Temperate, Torrid, South Temperate, and South Frigid). This system is used even in modern times.

50 Pliny (23–79), Roman scholar, writes *Natural History*, a mammoth encyclopedia containing most of the knowledge of the time. He also writes several books on natural science that exert a great influence on scientific thought for many centuries.

c.50–c.70
Dioscorides (c.40–c.90) writes the first systematic pharmacopoeia. His *De Materia Medica* in five volumes provides accurate botanical and pharmacological information. It is preserved by the Arabs, and when translated into Latin and printed in 1478, becomes a standard botanical reference for the next 1,500 years.

c.75 Hero of Alexandria (also called Heron; c.10–70), Greek mathematician and engineer, gives algebraic solutions to first and second degree equations. He also approximates square and cube roots and gives a formula for the area of a triangle as the function of its sides. In optics, he demonstrates that the angle of incidence equals the angle of reflection.

c.75 Pliny (23–79) recommends eating animal testicles to improve the sexual function of man.

c.75 Writings by Pan Ku (c.32–92) in China describe the workings of the abacus, made from bamboo.

98 Soranos of Ephesus, Greek physician, describes amenorrhea (absence of menstruation) and anorexia (loss of appetite) in women.

c.100 Aretaeus of Cappadocia (c.81–138), Greek physician, first uses the term "diabetes." He chooses the Greek word for siphon, indicating the intense thirst created by the disease.

c.100 Nicomachos of Gerasa (c.50–110), Byzantine mathematician, writes *Harmonices*, in which his theory of acoustics and harmonics reaches back to the ideas of the Greek philosopher Pythagoras (c.582–c.497 BC).

c.105 Modern papermaking from fiber is first traced to Ts'ai Lun (c.50-118), an official in the imperial court of China.

c.120 Aretaeus of Cappadocia (c.81–138), Greek physician, describes epilepsy, tuberculosis, tetanus, diphtheria, and diabetes.

c.130 Soranus of Ephesus, Greek physician, writes a treatise on midwifery and diseases of women. It contains rational ideas concerning infant hygiene and nutrition.

c.150 Ptolemy Claudius Ptolemaeus (also known as Claudius Ptolemy; c.90–c.168), Greek astronomer, writes *Megale Mathematike Syntaxis* (*Great Mathematical Composition*), which comes to be known as the *Almagest*. Besides the astronomical system it contains, it also extends the work of Hipparchus on trigonometry, especially spherical trigonometry.

150 Ptolemy (c.90–c.168) writes the eight-volume *Geographia*, which contains a world map as well as regional maps. The maps are conical projections and are the last example of scientific cartography for the next thirteen centuries.

c.150 Ptolemy (c.90–c.168) puts forth his idea of an Earth-centered universe. He accepts the theories of Hipparchus (c.190–c.120 BC) rather than Aristarchus (c.320–c.250 BC), and his incorrect notions of a geocentric system become dominant for the next 1,500 years.

c.150 Ptolemy (c.90–c.168) writes a treatise on optics, in which he considers the refraction of light. He offers an original approach that is both theoretical and experimental.

c.160 Galen (c.129–c.216), Greek physician, in his *De Usu Partium*, describes the pineal gland as a secretory organ that is important to thinking. He names it the pineal because it resembles a pine cone.

c.160 Bubonic plague (termed "barbarian boils") sweeps China.

c.166 Plague in Rome (possibly smallpox or bubonic plague) eventually kills millions throughout the weakening Roman empire.

c.180 Galen (c.129–c.216) cuts the recurrent laryngeal nerve of a pig and discovers that nerves control muscles. He becomes the greatest authority on physiology until the Renaissance, and many of his mistakes are taken literally as gospel.

185 Chinese astronomers observe what they call a "guest star" in the constellation Centaurus. It is a supernova that remains visible for 20 months.

c.300 Zosimus of Panopolis, Greek alchemist, establishes a school in Alexandria where pupils are taught basic chemical operations (filtration, fusion, sublimation, and distillation).

c.375 Lo Han of China writes *Hsiang Chung Chi*, in which he states that fossils were once living organisms.

c.375 Oribasius (325–403), Byzantine physician and pupil of Zeno, first describes the membrana tympani (of the ear) and the salivary glands.

c.400 Hypatia of Alexandria (c.370–415), astronomer, mathematician, and briefly head of the great library at Alexandria, writes commentaries on Diophantus (c.200–c.298) and Apollonius. As the recognized head of the Neoplatonist school of philosophy at Alexandria, she is noted as the only woman scholar of ancient times and the first woman mentioned in the history of mathematics. Her death by stoning by a fanatical Christian mob leads to the departure of many scholars from Alexandria and marks the beginning of its decline as a major center of ancient learning.

415 The Library of Alexandria is completely burned by religious zealots, thus destroying the most comprehensive collection of

ancient and classical scholarship in science and the arts. Much of the recorded knowledge of Western Civilization was lost.

c.425 During the reign of the Eastern Roman emperor Theodosius II (401–450), the Greek historian Zosimus is the first to note the electrolytic separation of metals.

c.450 Proclus (410–485), Greek mathematician and the last leader of Plato's Academy, argues that astronomers "do not arrive at conclusions by starting from hypotheses, as is done in the other sciences; rather, taking conclusions (i.e. the appearance of the heavens) as their point of departure, they strive to construct hypotheses from which effects conformable to the original conclusions follow with necessity."

c.460 Proclus (410–485), Greek mathematician and the last leader of Plato's Academy, writes commentaries on Euclid and Ptolemy and gives a historical outline of the evolution of Greek geometry. As the Neoplatonist head of the Academy at Athens, he is eventually driven into exile by Christians because of his pagan beliefs.

499 Aryabhata (476–c.550), Hindu mathematician and astronomer, writes his *Aryabhatiya*, which contains his significant description of the Indian numerical system. He also works on series, permutations, and arithmetic progressions and is one of the earliest to use algebra. He gives an accurate value for pi.

c.500 Chinese Daoist philosopher Tao Hung-ching (451–536) compiles a fundamental text of materia medica that is the basis of Chinese pharmacology for centuries.

c.500 During this century, the "Plague of Justinian" kills one million people.

510 Anicius Manlius Severinus Boethius (c.480–524), Roman philosopher, writes summaries of various scientific subjects including arithmetic, music, and geometry. He also introduces an improved abacus and uses numerals of Indian origin.

517 Johannes Philoponus (c.490–570), Alexandrian philosopher also called John the Grammarian, rejects Aristotle's idea that a body will only move as long as it pushed and offers his own theory of motion. He says that a body will keep moving in the absence of friction or as long as nothing opposes it. This is why the stars continue to move, he argues.

520 Ancius Manlius Severinus Boethius (c.480–524) begins his work *De consolatione philosophiae* in Latin. The book becomes one of the most widely read books—and a basic book on logic—in Europe in the Middle Ages.

525 Dionysius Exiguus (c.470–c.544), Christian monk, proposes a calendar that begins its dating system with the birth of Christ.

529 Benedict of Nursia (St. Benedict; c.480–c.547) founds the monastery at Monte Cassino in central Italy. It becomes, if not an actual medical school, at least an important center of scholarship in which medicine played a very great part. It also acquires great fame throughout the West, and its medical teachings are spread by the Benedictines to their monasteries scattered all over Europe.

529 Byzantine Emperor Justinian (c.482–565) closes the Academy (founded by Plato) in Athens and forbids pagan scientists and philosophers to teach. This causes an exodus of scientists to Persia.

c.530 Simplicius of Cilicia (c.490–c.560) argues that "gravity" describes the intensity of the tendency of bodies toward their natural place varied with their distance from that place.

c.535 Cosmas Indicopleustes, Alexandrian geographer and traveler, bases his model of the universe on Biblical accounts and attempts the first synthesis between early Christian concepts of the universe and classical ideas.

c.550 Varahamihira, Indian astronomer, writes his *Kochit Bhuvah*, in which he states that Earth is round and is circled by other planets.

595 In India, the first known use of our number system, with base ten and positional notation.

c.600 A flourishing Persian medical school, which has its roots in classical medicine and which brings together indigenous,

Hindu, and Syrian influences, develops at Jundishapur.

c.600 A glass making industry is established near Venice at this time.

c.600 Chinese texts make reference to the use of fireworks.

c.600 Isidore of Seville (c.560–636), Spanish scholar, compiles his *Etymologiae*, which contains much ancient knowledge. Its section reproducing the ancient medical texts helps connect monastic culture with Greek and Roman traditions.

c.600 Oil wells dug by hand are known to reach 600 feet deep in Japan.

c.600 The Chinese art of papermaking spreads to Japan, Korea, and westward to Persia.

602 Korean priests introduce astronomy and the calendar to Japan.

618 In China, a court newspaper begins publication. Several dozen copies of this court news publication are regularly printed.

c.700 For the next two centuries, the Arab doctors will systematically translate and adapt the ancient Greek medical texts. It is because of their conservation efforts that this knowledge is preserved and will eventually make its way to the West.

c.700 St. Benedictus Crispus, archbishop of Milan from 681 to about 730, writes his *Commentarium Medicinale*, an elementary practical manual in verse. It describes the use of medicinal plants for curing illnesses.

c.700 The Venerable Bede (673–735), English scholar, attempts to define "an atom of time" on order of the briefest sounds that humans can distinguish in speech.

c.750 With the rise of the Abbasid dynasty and the transfer of its capital to Baghdad, Hellenistic scientific culture, with its knowledge of the physical sciences, begins to be diffused throughout the Arab world (first in Syriac and then in Arabic) by the Nestorians.

c.750 Abu Musa Jabir ibn Hayyan (c.721–c.815), Arab physician and alchemist who is known in the West as Geber, notes the darkening effect of light on silver nitrate. This will eventually prove to be the basis for photography.

773 Al-Mansur (709–775), second caliph of the Abbasid dynasty, commissions a translation of the Hindu astronomical treatise *Siddhanta*, which dates to the first half of the sixth century.

c.775 Abu Musa Jabir ibn Hayyan (c.721–c.815), Arab physician and alchemist who is known in the West as Geber, discovers the principal salts of arsenic, sulphur, and mercury. He is known as the "father of Arab chemistry" for his contributions to distillation, sublimation, and his discovering such facts as heating a metal adds to its weight.

c.775 Alcuin (c.735–804), English scholar, speculates on the primordial Earth and says that its topography was smooth and its mountains were low.

785 Theophilos of Edessa dies this year. He is astrologer to the third Abbasid caliph, al-Mahdi, and translates Galen's (c.129–c.216) work into Syriac.

789 Charlemagne (c.742–814), king of the Franks and Holy Roman Emperor, introduces standard units of weight and measure in Europe, but this attempt to impose a uniformity on the many Medieval variants is not successful.

c.800 Mesue the Elder (also called Ibn Massawaih; 777–837), Christian physician writing in Arabic, prescribes animal testicles as an aphrodisiac and as a treatment for pulmonary tuberculosis.

c.800 Jabir ibn Hayyan Abu Musa (c.721–c.815), Arab physician and alchemist subsequently known as Geber, bases his chemical system "on two substances: sulphur, which...is hot and dry, and mercury, which is cold and wet. Since each contains all four elements, any other material can be formed by the proper combination of these two, and since we cannot know substance but only form, our search must aim at the most desired product, gold."

813 Abdalla Al-Ma'mun, Arab astronomer also known as Almanon, founds the Baghdad school of astronomy. He has Ptolemy's *Almagest* translated into Arabic and builds a major observatory in 829.

820 Muhammad ibn Musa Al-Khwarizmi (c.780–c.850), Arabian mathematician and Tashkent cleric, writes a mathematical treatise introducing the Arabic word "al-jabr" which becomes transliterated into "algebra." He develops the concept of a written process that delineates the steps needed to achieve a goal; his book on the subject gives this process its modern name, as his own name is distorted by translation into "algorism," which comes to mean the art of calculating or arithmetic. He also uses Hindu numerals, including the zero, and when his work is translated into Latin in the West, those numerals (which we now use) are called "Arabic numerals."

c.820 Muhammad ibn Musa Al-Khwarizmi (c.780–c.850) uses an Arab translation of Ptolemy to compile his own astronomical tables. He also estimates the size of Earth and is one of the few to offer a figure that is too large (40,000 miles).

821 The title of a medieval recipe book, *Mappae Clavicula*, first appears in the library catalog of the Reichenau monastery on Lake Constance. It is a randomly assembled text of formulas for pigments and painting, metallurgy, and glassmaking. It also contains information on how to make incendiary devices.

c.825 Al-Hajjai Ibn Yusuf (c.786–833), Arabian mathematician, makes the first Arabic translation of Euclid's *Elements.*

c.825 First information on the Hindu numerical system is found in a treatise titled *Algoritmi de Numero Indorum*, which is translated from the Arabic.

c.825 Mesue the Elder (also called Ibn Massawaih; c.777–c.837) writes a treatise called *Disorder of the Eye.* Ophthalmology flourishes at this time in Islamic medicine.

c.830 In Byzantium, Leo the Iatrophysicist (also called Leon of Thessalonica) compiles a medical encyclopedia that contains a large section on surgery.

c.850 Ali Rabban al-Tabari writes *The Paradise of Wisdom*, which provides Islamic medicine with its basic principles.

c.850 Islamic philosopher al-Kindi (813–873) writes his *De Medicinarum Compositarum Gradibus*, which attempts to base dosages of medicine on mathematical measurements.

c.850 John Scotus Erigena (c.810–c.877), Irish-born theologian and philosopher, writes his *De Divisione Naturae*, which offers the daring theory that Mercury, Venus, Mars, and Jupiter all orbit the sun.

850 Mahavira, Indian mathematician, writes his *Ganita-Sara-Sangraha*, which details Hindu geometry and arithmetic and is the only Hindu work dealing with ellipses.

c.850 Albumasar (787–886), Arabian astrologer, writes his *Introductorium in Astronomiam* and *De Magnis Coniunctionibus.* As the leading astrologer of the Muslim world, he maintains that the world was created when the seven planets were in conjunction in Aries, and that it will end when the same occurs in Pisces. His work becomes influential in the West in the Middle Ages.

c.850 Arab scholar Yaqub ibn–Ishaq al–Kindi (Al-Kindi; c.801–c.870), Arabian mathematician and astronomer, writes a work on Hindu numerals as well as a treatise on the geometry of optics. He also studies meteorology, the tides, and specific weights.

c.850 Arab scholar Yaqub ibn–Ishaq al–Kindi (Al-Kindi; c.801–c.870) advances an anatomical and physiological explanation of vision.

c.850 Moors in Spain prepare copper by reacting its salts with iron; the technique is a forerunner of electroplating.

c.860 Alfraganus, Arab astronomer, compiles a manual of astronomy that is a clear, comprehensive, and non-mathematical account of Ptolemaic astronomy. The medieval translation of this work is called *Elementa Astronomica* and is printed in 1493. It becomes popular and influential.

c.860 Al-Mahani, Persian mathematician and astronomer, is the first to state the Archimedean problem of dividing a sphere into two segments according to a given ratio in the form of a cubic equation.

868 The *Vajrasekhara-sutra* or the "Diamond Sutra" in Sanskrit is completed. This Tantric Buddhist text is considered the oldest complete printed book extant. It is actually a scroll.

870 Thabit ibn Qurra (836–901), Arabian mathematician, translates most of the major Greek mathematical works. His treatise on amicable or friendly numbers is the first example of original mathematical work in the Middle East.

c.875 Bertharius, the abbot of Montcasino from 857 to 884, writes two treatises, *De Innumeris Remediorum Utilitatibus* and *De Innumeris Morbis*, which give insight into the kind of medicine practiced in the monasteries.

c.875 Thabit Ibn Qurra (836–901), Arabian mathematician, translates astronomical works and adds his own observations and ideas to the Ptolemaic system of spheres. His work becomes accepted in the West.

896 Abu Bakr al-Razi (also known as Rhazes; c.845–c.930), Persian physician and alchemist, distinguishes between the specific characteristics of measles and smallpox.

900 Abu Kamil Shudja (850–930), Arabian mathematician, writes a treatise on algebraic methods applied to geometry, improving upon Al-Khwarizmi's algebra as applied to geometry. His work is later drawn upon by the West.

900 Albategnius (c.858–929), Arabian astronomer, reviews Ptolemy's work and makes many small corrections. He determines the time of equinox within an hour or two and further clarifies the angle at which Earth's axis is tipped to its plane of revolution. As the greatest of the Islamic astronomers, he introduces new types of mathematical computations to astronomy and is the first to make use of a table of sines for that purpose.

c.900 Qusta ben Luga al-Ba'labakki, Greek translator, translates the works of Diophantus, Aristarchus, and Hero and develops the use of tangents and cotangents in trigonometry.

c.900 Rhazes (c.860–c.930), Persian physician and alchemist, is the first to divide all substances into the grand classification of animal, vegetable, and mineral. He also subclassifies minerals into metals, volatile liquids (spirits), stones, salts, and others. He applies his knowledge of chemistry to the preparation of medicine.

900 Native Americans use the plant *Lithospermum ruderale* as a contraceptive drug.

c.900 First medical books written in Anglo-Saxon appear. *Lacnunga* and the *Leech Book of Bald* appear and have some botanical sections.

c.912 Ahmad Ibn Yusif, Egyptian mathematician known in the West as Hametus, writes his *Liber de Proportione et Proportionalitate*, which greatly influences medieval mathematical thinking.

914 Abu Utman, Arabian mathematician and physician, translates the tenth book of Euclid.

914 Al Masudi, Arab historian and geographer, records accurate principles on evaporation and the causes of ocean salinity. He is the first in the East to combine history and scientific geography in a major work. He is known as the "Herodotus of the Arabs."

918 Arab Caliph al-Muqtadir founds a hospital in Baghdad and chooses Rhazes (c.860–c.930), to be its director.

c.950 'Abd al-Rahman al-Sufi (903–986), Arabian astronomer, revises Ptolemy's catalog of fixed stars and prepares an accurate map of the sky that becomes a standard work in the West for several centuries.

c.950 Alchazin, Arabian mathematician and astronomer also called Al-Kazin, becomes the first Arab to solve the cubic equation by means of conic sections.

c.950 Al-Imrani, Arab mathematician and astronomer, comments on the work of Abu Kamil and makes a Latin translation of his work that becomes very influential in the West.

c.950 Members of Ism'iliya ("Brethren of Purity"), an Islamic sect, compile a corpus of alchemical works that are later attributed to Geber, the mysterious alchemist who is supposed to have lived in the eighth century.

c.955 The Jewish "Prince of Medicine," Isaac Israeli, dies. He writes classic works on fever and uroscopy, as well as a *Guide of the Physicians.*

960 Abul Wafa (940–998), Persian astronomer and mathematician, describes the vibrations of the moon. Also called variation, this is the oscillation or inequality in the moon's motion.

c.975 Abu Mansur al-Muwaffaq writes his *Liber Fundamentorum Pharmacologiae*, which gathers and classifies almost 600 cures.

c.980 Abul Wafa (940–998), Persian mathematician and astronomer, comments on the Greek mathematicians and invents a method for computing sine tables. The tables give the sine of half a degree correct to nine decimal places. He also introduces the new trigonometric functions of the secant and cosecant.

c.980 Gerbert (c.945–1003), French scholar, helps initiate the rebirth of learning in Europe, especially in mathematics. As one of the first Christians to study in the Muslim schools of Spain, he reintroduces the abacus to the West and uses Arabic numerals (although not a zero). Gerbert is not only a profound scholar, but in 999 he is elected pope, taking the name Sylvester II.

c.980 Abu Al–Qasim Al–Zahravi (Abucasis) creates a system and method of human dissection along with the first formal specific surgical techniques.

c.988 Al-Kuhi, Arabian mathematician and astronomer, solves and discusses the conditions of solvability of equations higher than the second degree.

c.1000 Abbo of Fleury (c.947–1004), writes his *De Numero et Pondere Super Calculum Victorii*, a commentary on ancient computation tables.

c.1000 Alhazen (also known as Abu Ali Hasan Ibn Al–Haitham; 965–1038), Arabian physicist, turns his attention to astronomy and becomes the first Eastern scholar to study the physical nature and composition of the heavenly bodies. His theories later become widely known in Europe.

c.1000 Al-Biruni (973–1048), Persian scientist, historian, and astronomer, determines specific weights using a pycnometer similar to a modern instrument that measures and compares densities of solids and liquids. The device resembles a short, wide bottle with what looks like a thermometer placed in its neck.

c.1000 Gerbert (c.940–1003), French scholar, Pope from 999 to 1003 (ruled as Sylvester II), consults Arab works on astronomy, translates them, and builds several astronomical instruments.

c.1000 Islamic surgeon Abu-l-Qasim al-Zahrawi (c.936–1013) writes his *Vademecum* in Cordova, Spain. It is eventually translated by Gerard of Cremona.

c.1000 Ibn Yunus (c.950–1009), Muslim astronomer working in Cairo, Egypt, publishes a set of astronomical and mathematical tables of planetary motion that becomes a standard work for the next two centuries.

c.1000 Alhazen (Arab physicist also known as (Abu Ali Hasan Ibn Al–Haitham; 965–1038), Arabian physicist, rejects the idea that people see because their eyes send out a light that reflects back from an object. He argues correctly that light comes from the sun or another source and reflects from the object into the eye. He studies all aspects of light, especially reflection and refraction and also offers an exploration of rainbow formation.

c.1000 Alhazen (Arab physicist also known as (Abu Ali Hasan Ibn Al–Haitham; 965–1038), in his *Opticae Thesaurus*, introduces the concept that light rays emanate in straight lines in all directions from every point on a luminous surface.

c.1000 Ibn Sina, or Avicenna (980–1037), argues against the Aristotelian notion that "every motion occurs through a power in the moving object by which it is impelled."

c.1000 Ibn Sina, or Avicenna (980–1037), publishes *Al-Quanun*, or Canon of Medicine, in which he holds that medicines can be discovered and tried by experiment or by reasoning.

c.1000 Ibn Sina, or Avicenna (980–1037), advances a hypothesis on orogeny (mountain formation). Avicenna argues that: "Either they are the effects of upheavals of the crust of Earth, such as might occur during a violent earthquake, or they are the effect of water, which, cutting itself a new route, has denuded the valleys...." He also states that: "It would require a long period of time for all such changes to be accomplished...."

c.1000 Alhazen (c.965–1038), Arab physicist also known as Abu Ali Hasan Ibn Al–Haitham), documents the phenomenon of the camera obscura in detail and notes that the image is sharper with a small hole and more diffuse with a larger hole.

1005 Scientific academy with an astronomical observatory is established at Cairo at the request of the Fatimid caliphs. This marks a revival of Egyptian astronomy.

1006 A supernova that remains visible for year is recorded in China, Europe, and the Arab lands.

1007 Ibn Yunus (c.950–1009), Arabian astronomer, completes the compilation of the *Hakemite Tables*, which contain a wide range of astronomical data and measurements.

c.1010 Ibn Sina, or Avicenna, (980–1037), Persian physician, accepts the impetus theory of Johannes Philoponus (c.490–570), and his anti-Aristotelian ideas influence the West.

1010 The School of Salerno flourishes in Italy. Begun around the start of the ninth century, it reaches its greatest influence at this time and preserves its fame to the end of the fourteenth century. This medical school in southern Italy grants the first medical diplomas and becomes a place to which students from Europe, Asia, and northern Africa flock.

c.1020 Al-Biruni, (973–1048), Persian scholar, historian, scientist, and astronomer, writes an astronomical encyclopedia called *Mas'udic Canon*, which summarizes the astronomical knowledge of his time.

c.1020 Alkarki, Arabian mathematician, writes a treatise on algebra considered the best produced by an Arabian scholar. He is also the first to work with higher roots.

c.1020 Ibn Sina, or Avicenna (980–1037), describes the structure of the thorax, heart, and eye. He also offers specific descriptions of the heart valves.

1021 "Dancing Mania" or St. Vitus' Dance breaks out in Europe. This is a convulsive, neurological disease also called chorea; it is usually associated with rheumatic fever. Its victims seem possessed, and they exhibit irregular, involuntary movements. During this time, persons in the grip of this mania attended the chapel of St. Vitus, who is believed to have curative powers, thus giving the disease its name.

c.1025 Al-Biruni (973–1048), Persian scholar, historian, scientist, and astronomer, explains natural springs by the laws of hydrostatics, determines accurately the specific weight of eighteen precious stones and metals, and states that the Indus valley once was under water.

c.1025 Ibn Sina, or Avicenna (980–1037), Persian physician, is argued to have written an alchemical treatise called *De Anima* that becomes a standard text in medieval Europe. He does not assert that transmutation (conversion of ordinary metals into gold or silver) is possible.

c.1025 Guido d'Arezzo (995–1050), Italian musicologist, introduces a system of musical notation by placing neumes (symbols of single notes) on a grid of 4 or 5 lines, similar to modern staff notation. He also develops the hexachord, a system of 6 notes on a musical scale, and names them "ut, re, mi, fa, sol, la."

c.1025 Alhazen (c.965–1038), Arab physicist also known as Abu Ali Hasan Ibn Al–Haitham, advances techniques and theory in the study of light and optics.

c.1025 Al-Biruni (973–1048), Persian physician, astronomer, and mathematician, makes a fairly accurate calculation of the specific weights of eighteen precious stones and metals. He uses the methods employed by Archimedes.

1030 Al-Biruni (973–1048), Persian physician, mathematician, astronomer, and philosopher, writes a major summary of mathe-

matics and astronomy as well as the best medieval account of Hindu numerals. He also investigates geometric progressions and studies what become known as albirunic problems (the trisection of an angle and other problems that are unsolvable with only a ruler and compass). He is one of the greatest scientists of the Islamic world.

c.1050 Hermannus Contractus (1013–1054), German abbot of Reichenau, writes a treatise on the astrolabe.

c.1050 Michael Constantine Psellus (1018–c.1078), Byzantine philosopher and statesman, includes astronomy among his voluminous writings. He is regarded as the last Greek writer on astronomy of note.

c.1050 Solomon ben Judah Ibn Gabirol, or Avicebron, held that every material thing possesses a "common corporeity," which is continuous through the universe.

1054 Supernova of the Crab Nebula is recorded in China and by Native Americans.

1066 Appearance of a large comet is recorded in England and is linked to the successful invasion of England by William of Normandy (1027–1087). Known today as Halley's Comet, it is also depicted in the Bayeux Tapestry, which commemorates William's triumph.

1074 Omar Khayyam (1048–1131), Persian astronomer, philosopher, and poet, reforms the Muslim calendar and produces one that better matches astronomical reality.

c.1075 Franco Liege, superintendent of the French cathedral school of St. Lambert, invents what some claim to be the first useful torquetum. This astronomical observational device evolves into a complicated set of inclined and rotating tables composed of several different instruments that allow the skilled user to calculate the altitude and azimuth of heavenly objects.

c.1075 Manegold of Lautenbach (c.1030–1103), Alsatian philosopher, argues that Christian philosophers must give up any interest in physics and not attempt to understand natural phenomena using only their reason.

1079 In 1079, Omar Khayyam (1048–1131) publishes his *Treatise on Demonstrations of Problems in Algebra*, which includes a complete classification of cubic equations and their geometric solutions.

c.1100 Updated version of *Mappae clavicula* (a manuscript with recipes for soap, dyes, and alchemical formulas) contains the first description of a liquid, distilled from wine, that will catch fire. It is named "alcohol" in the sixteenth century.

1100 Distillation techniques advance to the point where distillates can be captured by cooling.

1115 Al-Khazini (fl.1115–1130), Arabian astronomer, compiles what becomes known as the *Sanjaric Tables* which give positions of the stars for the years 115–1116.

c.1116 Abraham bar Hiyya Savasorda (c.1065–c.1136), Jewish philosopher, mathematician, and astronomer in Spain, leads the revival of Hebrew as a written language of western Mediterranean Jews. A Latin translation of his geometry textbook is long used in Europe.

1120 Adelard of Bath (c.1090–c.1150), English scholar, makes the first Latin translation of Euclid's *Elements* from an Arabic version. This serves as the major geometry textbook in the West. He also introduces Arab trigonometry to the West and uses Arabic numbers.

c.1120 Awhad al-Zaman Abu'l-Barakat al-Baghdadi, Kitah al-Mu'tabar, disputes Aristotle's notion that a constant force produces a uniform motion.

1121 Al-Khazini argues that gravity acts towards Earth's center.

1137 Al-Khazini writes a book in which he offers tables of specific densities and a general description of the laws of gravity.

1137 St. Bartholomew's hospital is founded in London.

c.1140 Adelard of Bath translates Al-Khwarizmi's astronomical *Tables* and begins the introduction of Arab astronomy to the West.

1140 Bologna, Italy, begins to develop as a major European medical center. In the next century, the Italian physician Taddeo Alderotti (c.1233–1303) opens a school of medicine there.

1140 Roger II of Sicily (1095–1154) introduces a compulsory examination for medical doctors and grants the School of Salerno official status and his protection.

1144 First translation of Arabic alchemical manuscripts begins in Spain, introducing European scholars to alchemy.

c.1150 Atscharja Bhaskara (1114–1185), Indian astronomer and mathematician, writes his *Siddhanta S'iromani*, in which he gives several approximations for pi and offers what is believed to be one of the first descriptions of a machine for perpetual motion.

c.1150 Hildegard of Bingen (1098–1179) publishes *The Book of Simple Medicine*, a treatise on the medicinal qualities of plants and minerals.

1175 Gerard of Cremona (c.1114–1187), ltalian scholar and most important translator in Toledo, Spain, organizes the largest translators' school of the Middle Ages in Toledo and translates from Arabic into Latin hundreds of works on physics and mechanics, medicine, alchemy, astronomy and astrology, and logic and philosophy. Many of these works came from the original Greek.

1175 Gerard of Cremona (c.1114–1187), Italian scholar, translates Ptolemy's *Alamgest* and Euclid's *Elements* into Latin for Western scholars.

c.1175 Averroes (1126–1198), Arabian philosopher, assembles Galen's (c.129–c.216) medical works and writes commentaries on Aristotle.

c.1175 Chu Hsi of China writes his *Chu Tsi Shu Chieh Yao*, in which he states that fossils were once living organisms.

1202 Leonardo Fibonacci (1170–1250)—also known as Leonardo of Pisa (son of Bonacci)—publishes *Liber Abbaci* (which is subsequently updated and re-released in 1228). This is the work that first gives us Fibonacci numbers (largely ignored for the next three centuries); it also includes methods of calculation and multiplication. This book also marks the beginning of the use of the modern number system.

c.1210 Richard of Wallingford (c.1292–1336), English scholar, makes the first known recording of tides for the purpose of prediction of floods.

1215 Robert Grosseteste, (c.1175–1253), English scholar, as well as bishop of Lincoln and the first chancellor of the University of Oxford, advocates experimental procedures to complement scientific investigation of cause and effect.

1217 Michael Scot (c.1175–c.1234), Scottish scholar and mathematician, translates the work of Arabian scholar Alpetragius (d. c.1204) and awakens Europe to Aristotelian ideas on astronomy.

1222 University of Padua, Italy, is founded and becomes a medieval center of learning.

1224 Frederick II (1194–1250), Holy Roman Emperor, king of Germany and Sicily, and grandson of Roger II of Sicily, issues laws regulating the study of medicine. His requirement for proper examinations did much to elevate the status of respectable physicians and diminish the number of quacks. He also founds the University of Messina (Sicily).

1230 Frederick II (1194–1250), Holy Roman Emperor, commissions the translation of the *Almagest* into Latin from the Arabic.

c.1230 Johannes de Sacrobosco (c.1200–c.1256), English mathematician and astronomer also called John of Holywood, writes his *De Arte Numerandi seu Algorismus Vulgaris*. This simple and practical book of arithmetic greatly influences the acceptance of Hindu-Arabic numerals in the West.

1230 Johannes de Sacrobosco (c.1200–c.1256), English mathematician and astronomer also known as John of Holywood, writes his *Tractatus de Sphaera Mundi*, which popularizes the Ptolemaic system.

1230 Jordanus Nemorarius, German mathematician and physicist, writes his work on gravity titled *Gravitas Secundum Situm*. He also writes on statics and includes much from Aristotle on the law of the lever and inclined planes.

c.1230 Robert Grosseteste (c.1175–1253), English scholar, writes his *De Generatione*

Sonoroum, in which he describes sound as a vibrating motion that passes through the air from its source to the ear.

c.1230 Scholars in the Middle Ages debate explanations of natural phenomena, including the apparent movements of the celestial sphere.

c.1230 Vincent of Beauvais (c.1190–c.1264) publishes a folio or encyclopedia of approximately six thousand pages in length. The work, *Speculum majus*, contains translations of Greek and Arabic books on philosophy, science, and mathematics.

1240 Encyclopedist Bartholomeus Anglicus (c.1203–1272) writes *De Proprietatibus Rerum*, which contains information on metals as well as on plants and herbs.

c.1240 Johannes de Sacrobosco (c.1200–c.1256), English mathematician also called John of Holywood, writes his *Algorismus Vulgaris*, which becomes a standard university text.

1241 Frederick II (1194–1250), Holy Roman Emperor, issues a law that allows dissection of cadavers and regulates surgery and pharmacy.

1242 Roger Bacon (c.1220–c.1292), English scientist and philosopher, is among the first in the West to mention gunpowder and provide recipes for its manufacture. There is no doubt, however, that gunpowder originated in China, perhaps in the eleventh century.

1247 Ch'in Kiu-shao, Chinese mathematician, writes *Su-shu Chiu-chang*, which deals with indeterminate equations. He also uses the symbol 0 for zero.

1248 Li Yeh, Chinese mathematician, writes *T'se-yuan Hai-ching*, in which he designates negative numbers by drawing a cancellation mark across the symbol.

c.1250 Richard Anglicus of England writes *Correctorium Alchymiae* and divides minerals into two classes of metals according to their physical origins.

c.1250 Arab scientist Ibn al-Nafis (d. 1288) first describes the major functions and organization of the pulmonary circulatory system.

c.1250 Gerard of Brussels, Flemish physicist, writes his *Liber de motu*, which is the first treatise on the study of motion from a purely kinematic point of view.

1252 King Alfonso X of Castile (1221–1284) encourages the preparation and publication of a revised set of planetary tables. Called the "Alfonsine Tables," they are published the very day he ascends to the throne and they become the basis of all astronomical observations for the next two centuries.

1255 Roger Bacon (c.1220–c.1292), English scholar and scientist, writes of the roundness of Earth and estimates the distance of the farthest stars.

1259 Hulagu Khan, Mongol conqueror, founds an astronomical observatory at Maragha in northwest Persia on the advice of the Persian astronomer Nasir al-Din al-Tusi (1201–1274). A set of tables called *Zij-Ilkhani* is later compiled on the basis of observations from this observatory.

1260 Albertus Magnus (1193–1280), German scholar, writes his *De Rebus Metallicus et Mineralibus*, in which he describes arsenic so precisely that he is sometimes credited with discovering it. He also compiles a list of one hundred minerals and notes the existence of fossils.

1260 Brunetto Latini (1230–1294), Italian encyclopedist, writes his famous *Tesoro*, in which he mentions the use of a compass at sea and the superstitions surrounding its mysterious origins and powers. This work becomes best known in its French version (*Le Livres dou Tresor*).

1260 Giovanni Campano (1220–1296), Italian translator also called Campanus, provides a new translation of Euclid's *Elements* from the Arabic, which drives out all earlier versions and serves as the basis of the later mechanically-printed editions.

1266 Hugh and Theodoric Borgogoni argue that surgical patients should be put to sleep with sponges soaked in narcotics. They also recommend a crude cleaning of wounds and that torn edges be brought together by stitching.

1267 Roger Bacon (c.1220–c.1292), English scholar and scientist, writes his *Opus*

Majus, which includes sections on optics and physics.

c.1267 Roger Bacon (c.1220–c.1292), English philosopher and scientist, asserts that natural phenomena should be studied empirically.

1269 Petrus Peregrinus, French scholar also called Pierre de Maricourt, writes a small treatise on the compass titled *Epistola de Magnete* and discusses the nature and fundamental properties of magnetism. This is believed to be the first Western account of a compass.

c.1270 William of Moerbeke (c.1215–c.1286), Flemish scholar, translates the mathematical works of Greek mathematician and engineer Archimedes. Although his translations are extremely literal, they are well received and serve as the basis for the first printed versions in the early sixteenth century.

c.1270 Witelo (1230–1275) of Silesia, also called Vitellio, writes *Perspectiva*, a systematic treatment of the optics of the Arabian physicist Alhazen. It deals with refraction and reflection as well as the twinkling of stars (caused by motion).

c.1275 Roger Bacon (c.1220–c.1292), English scholar and scientist, advocates using chemicals in the practice of medicine.

c.1275 William of Saliceto creates the first established record of a human dissection.

c.1277 John Pecham (c.1230–1292), English scholar, writes *Perspectiva Communis*, which becomes the standard textbook on optics for the next three centuries. He states that eyes see by the receipt of rays from the object.

c.1280 Peter Olivi (1248–1298), French scholar, develops the theory of impetus, which states that a moving body may continue in motion even when the propelling force is removed.

1282 Ristoro d'Arezzo (c.1220–1282) of Italy writes on the composition of Earth and states that stars create mountains by drawing earth above the water. This notion is later reflected in the writing of Dante Alighieri (1265–1321). D'Arezzo also says that Earth's interior is in a molten state.

c.1290 Medieval scholars Giles of Rome (1247–1316) and Bernard of Verdun suggest that the dispute between Aristotelian and Ptolemaic astronomy should be settled by observational evidence. This shows the beginning of the scientific method.

c.1300 Arnold of Villanova (c.1235–1311), Spanish alchemist, influences medicine with his *Breviarum Practice* and *Regimen Sanitatis*. He is affiliated with the Montpelier school.

c.1300 Johannes Duns Scotus (c.1266–1308), Scottish philosopher, discusses the nature of physical laws and distinguishes between causal laws and empirical generalizations. This is an important step in the beginnings of the scientific method.

1302 First formally recorded post-mortem or judicial autopsy is performed in Bologna, Italy, by Italian physician Bartolomeo da Varignana. A postmortem is ordered by the court in a case of suspected poisoning.

1303 Simon of Genoa (Simone de Cordo), Italian botanist and physician, dies but leaves behind his polyglot medical dictionary. With the invention of mechanical printing in the next century, it becomes the first medical dictionary to be printed. It is published in Milan, Italy, in 1473 and is titled *Synonyma Medicinae sive Clavis Sanationis*.

1304 Theodoric of Freibourg (also called Dietrich von Freiberg; c.1266–1308) writes *De Iride*, in which he discusses water and rainbow formation as well as the idea that all colors are simply combinations of lightness and darkness in different proportions.

1304 Giotto di Bondone begins a new physical and chemical process of painting frescoes with his work at the Scrovegni Chapel, Padua, Italy.

1308 The Council of Venice authorizes one anatomical dissection per year.

1315 Mondino de'Luzzi (c.1275–1326), Italian anatomist, makes his first public dissection of a female subject. He teaches anatomy at the medical school in Bologna, Italy, and writes the first book devoted entirely to anatomy.

1319 First criminal prosecution for body-snatching is conducted. Obtaining cadavers for anatomical research will be a problem into the nineteenth century.

1323 In keeping with Pope John XXII's 1317 edict against the practice of alchemy, the Dominican order threatens with excommunication any church member who practices alchemy and who does not destroy any alchemical books he owns.

1323 William of Ockham (1280–1349), English scholar, in *Questiones super quattuor libros sententiarum*, introduces a distinction between the states of "being in motion" and "being moved." In the modern era these states are described as dynamic motion and kinematic motion.

1325 Thomas Bradwardine (c.1290–1349), English mathematician, writes the first of his many works on arithmetic and geometry. He also develops mathematical formulae for physical laws, leading to the development of quantitative measurement of physical processes.

1326 Richard of Wallingford (c.1292–1336), English mathematician, invents a clock that shows the time and season as well as the course of the sun, moon, and planets.

1328 A publication of Merton College, Oxford, asserts the Mertonian Rule wherein the measure of uniform acceleration is shown to be its medial velocity.

1330 Barnabas da Reggio, Italian physician, writes a book on ophthalmology called *De Conservanda Sanitate Oculorum.*

1330 Jean Buridan (c.1300–c.1385), French philosopher, rejects Aristotle and puts forth a new theory of motion that he also applies to a theory of the heavens. He argues that once God set the planets in motion, they would continue moving on their own, without continuous intervention. He holds that the same laws of motion apply in the heavens as they do on Earth.

c.1330 Petrus Bonus, Italian physician and alchemist also known as Bonus Lombardo or Buono Lombardo of Ferrara, writes *Pretiosa Magarita Novella*, which describes the prevailing alchemical theories.

c.1330 Richard of Wallingford (c.1292–1336), English mathematician, writes on arithmetic and trigonometry.

1330 William of Heytesbury, English logician and mathematician, contradicts Aristotle's ideas about falling bodies, pointing out that a freely falling body goes three times as far in the second of its fall than it does in the first second.

c.1330 William of Ockham (c.1288–c.1348) calls for a science that is separate from religion and for one that seeks simple explanations. He asserts that when two hypotheses are equally capable of explaining what we observe the simplest of the two should be accepted; this idea comes to be known as "Ockham's razor."

1333 A public botanical garden is established in Venice, Italy, to grow herbs that have medical uses.

c.1340 Giovanni Bocaccio (1313–1375), Italian author, writes on the origins of fossils in his *Filocolo* and states that the sea once covered the earth.

c.1340 Johannes de Lineriis of France writes his *Algorismus de Minutiis*, in which he uses fractions and includes the practice of placing the numerator over the denominator, using a horizontal line dividing the two.

1340 Levi ben Gerson (1288–1344), Jewish astronomer in France, writes his *Sefer Tekunah*, in which he attempts to replace the Ptolemaic system and to rationalize Jewish cosmology.

1344 Gregory of Rimini (c.1323–1358), Italian natural philosopher also called Gregorio Novelli da Rimini), discusses the concepts of continuity and infinity in mathematics.

1348 A three-year epidemic caused by *Yersinia pestis* begins and kills almost one-third of the population of urban Europe. In the aftermath of the epidemic, measures are introduced by the Italian government to improve public sanitation, marking the origin of public health.

c.1350 Albert of Saxony (c.1316–1390), German philosopher, further develops the theory of impetus and distinguishes between uniform and irregular motion. He also

distinguishes between the center of gravity and a geometric center.

c.1350 Giacomo Dondi (1298–1359), Italian physician and astronomer, writes his *Tractatus de Cause Salsedinis*, in which he discusses the salinity of the oceans as well as the phenomenon of the tides. He suggests that the combined effects of the sun, moon, and planets have an effect on Earth's tides. He also is the first to recommend the extraction of salts from mineral waters for medicinal purposes.

c.1357 Albert of Saxony (c.1316–1390), German philosopher and mathematician, offers an early version of isostasy. This geological notion implies that rock formations slowly find their natural level by sinking or rising according to their densities.

1373 Charles V (1338–1380), king of France, opens what becomes the National Library in Paris.

1377 The first quarantines on land are imposed at Reggio nell'Emilia, Italy, as a check against the spread of the plague.

1380 Charles V (1338–1380), king of France, bans alchemical research in his kingdom and makes possession of any instruments of alchemy a crime.

1388 Richard II (1367–1400), king of England, establishes the first sanitary laws in England.

1391 Geoffrey Chaucer (c.1343–1400), English writer, writes *A Treatise on the Astrolabe*, in which he describes how to build and use this astronomical measuring instrument.

c.1400 Al-Kashi, Persian mathematician and astronomer, writes a short work on arithmetic and geometry and is the first to use decimal fractions.

c.1400 Whiskey is distilled in Ireland and Scotland from a fermented mash of grain, primarily barley. Its name in Celtic, Irish Gaelic, and Scots Gaelic means "water of life."

1404 Henry IV (1366–1413), king of England, prohibits the practice of alchemy in his kingdom.

1410 Benedetto Rinio publishes 450 paintings of plants, botanical notes, and extensive citations in a botanical treatise that uses both Greek and Arabic names for plants.

1418 The Great Council of Venice bans any practice of alchemy. Its practitioners run the risk of being accused of witchcraft.

1424 Ulugh Beg (1394–1449), Mongol astronomer, builds an astronomical observatory in Samarkand (central Asia) where he had founded a university four years before. He also publishes his own star map, the first new one since Hipparchus, about 1,500 years before.

1430 Leon Baptista Alberti invents his cipher machine—a polyalphabet system utilizing a cipher disk to encode and decode messages.

1450 Johann Gutenberg (c.1398–c.1468), German inventor, first invents printing with movable type. To the Chinese inventions of paper and printing with blocks, he adds two innovations—a method of casting metal type and an ink that adheres to the cast metal—and lays the technical foundations for what will become a revolutionary printing industry.

1451 Bernardo di Rapallo of Italy devises a perineal operation for kidney stones.

1456 During this year, various chronicles record the passage of a very large comet. This is the same one for which Edmund Halley (1656–1742) will later achieve fame.

1457 First known piece of medical printing (typographic printing) is the Mainz *Calendarium*, a bleeding calendar.

1457 Peter Schöffer (1420–c.1502), German printer and son-in-law of German inventor and goldsmith Johann Fust (c.1400–1466), prints his *Psalter*, using letters that incorporate both blue and red ink. He uses type made of two parts that fit together but are inked separately.

1457 The first printed book to give both the name of the printers and the date of printing is the *Psalterium Latinum*.

1461 Georg von Peurbach (1423–1461), Austrian mathematician and astronomer, dies before he can complete a new set of planetary tables. They are significant because of his use of Arabic numerals to prepare a table of sines.

1461 The first dated book with woodcut illustrations is *Der Edelstein*, a book of fables by Ulrich Bonner of Switzerland. It is

also the earliest dated book in the German language. It is printed by Albrecht Pfister.

1463 Nicholas of Cusa (1401–1464), German cardinal, publishes his *De Ludo Globi*, in which he applies the impetus theory to the motion of a spherical ball.

1465 The first printed book in Italy is Cicero's *De Oratore*, printed by Conrad Sweynheym and Arnold Pannartz at Subiaco.

1466 The first edition of the printed Bible in a modern language is Johann Mentelin's version printed in German at Strasbourg.

1469 First scientific book to be printed after the invention of typographic printing is Pliny's *Historia Naturalis.* It becomes very influential and sees scores of editions.

1472 First Latin translations of the biological works of Aristotle (384–322 BC), appear in print. His *Historia Animalium*, *De Partibus Animalium*, and *De Generatione Animalium* sometimes appear under the overall title *De Animalibus.*

1472 Regiomontanus (1436–1476), German astronomer, observes a comet and becomes the first to make comets the object of real scientific study. Heretofore they were regarded with superstitious terror. He also revises Ptolemy's work and founds an observatory at Nuremberg.

1472 The first illustrated book on a technical subject is *De Re Militari*, a book on warfare by Roberto Valturio.

1472 The standard astronomical textbook of the Middle Ages, *Sphaera Mundi*, is first published. It was written in the thirteenth century by the English mathematician and astronomer Johannes de Sacrobosco (c.1200–c.1256) and continued in use to the end of the sixteenth century. It is the first exposition of the Ptolemaic system by a European.

1473 *Philobiblon* by medieval writer Richard de Bury (1287–1345) is first published. This book uses the word "geology" to describe the science or law of the earth as opposed to "theology," which is the science of the divine.

1473 First Latin translation is made of *De Rerum Natura,* written by the Roman philosopher and poet Lucretius (c.95–c.55 BC). It is through this translation that the atomism of Democritus becomes known in the West.

1473 First printing of Avicenna's *Canon Medicinae* is made and becomes one of the most famous medical texts in the history of medicine.

1473 The earliest known printed book to contain music and musical notes is the *Collectorium super Magnificat* by Jean Gerson. It is printed at Esslingen by Conrad Fyner.

1474 Georg von Peurbach (1423–1461), Austrian mathematician and astronomer, has his textbook of planetary theory published posthumously. Titled *Theoricae Novae Planetarum*, it had been completed by Peurbach in 1454 but was never published.

1474 The first book printed in English is the *Recuyell of the Histories of Troy*, printed in Belgium by William Caxton (c.1422–1491) of England. This and most of his following books are printed in English rather than Latin.

c.1475 Foresights for aiming a hand-held firearm begin to come into use.

1475 The first dated printed book in Hebrew is printed at Reggio di Calabria, Italy, by Abraham ben Garton. It is a *Commentary on the Pentateuch* by Rabbi Salomon Rashi.

c.1475 When rich deposits of alunite (aluminum sulfate in crystal form) are discovered at Tolfa, Italy, the Pope is determined to exploit them to free Europe from its dependency on the Arabs. Two years after the discovery, the mines employ seven thousand people.

1476 The first dated book printed in the French language is *La Légende Dorée.* It is printed at Lyons, France, by Guillaume Le Roy and Barthelemy Buyer.

1476 The first separately-displayed title page in a printed book appears in the *Kalendario* of German astronomer Johann Müller, known as Regiomontanus (1436–1476). It takes several years before the practice of putting the title accompanied by the date, place, and printer's name on a separate page becomes common.

1477 The first copper-plate engravings to be printed as an integral part of a book appear in *Monte Santo de Dio* by Antonio Bettini (1396–1487), bishop of Foligno, Italy.

1477 William Caxton (c.1422–1491) of England prints *The Dictes or Sayengis of the Philosophers*, the first dated book printed in England.

1478 The first edition of *Chirurgia* by medieval surgical authority Guy de Chauliac (c.1300–1367) of France is published in Paris.

1480 The first printed book dealing entirely with music is the *Theoricum Opus Musicae* by Franchinus Gafurius, also called Franchino Gafori (1451–1522). It is printed in Naples, Italy, by Francesco di Dino.

1481 The first illustrated book produced in England is *The Mirrour of the World*, printed by William Caxton (c.1422–1491).

1482 Erhard Ratdolt, German printer and typographer, produces the first printed edition of Euclid's *Elements*. It is the first printed book to be illustrated with geometric figures.

1482 First Western printing of Averroes's *Colliget*, a general medical encyclopedia, is published in Ferrara, Italy.

1483 The *Alfonsine Tables* are first printed in book form. Until now, these planetary tables commissioned by the Spanish monarch Alfonso X (1221–1284) existed only in manuscript form. They are considered the best available until the sixteenth century.

1483 The first printed versions of the scientific botany of the Greek botanist Theophrastus (c.371–287 BC), appear, titled *Historia Plantarum* and *De Causis Plantarum*.

1483 Giovanni Arcolani (d. 1484), Italian surgeon, publishes his book, *Practica*, in which he recommends for the first time the filling of teeth with gold.

1484 Bernard Walther (1430–1504), German astronomer, uses weight-driven clocks in the Nuremberg Observatory.

1484 The first printing press owned and operated by a woman is that of Anna Rugerin of Germany who takes over her late husband's business.

1485 Book censorship begins in Mainz, Germany, with the first decrees prohibiting certain "dangerous" books. The Catholic Church will eventually institutionalize this practice and issue its *Index* of prohibited books.

1485 Erhard Ratdolt, German printer and typographer, publishes the first printed book to use more than two differently colored inks on the same page. The book is *De Sphaera* by Johannes de Sacrobosco (c.1200–c.1256).

1486 Gregor Reisch of Germany publishes the first edition of his *Margarita Philosophica*, an extremely popular encyclopedia that deals with many sciences, including optics. It attempts to explain the nature of light and the mechanism of vision.

1486 Bartholomeu Dias sails around the Cape of Good Hope, spurring an era of seafaring discoveries and advances in the techniques and technology of navigation.

1490 First printing in Latin of Galen's (c.129–c.216) works, titled *Opera*. His anatomical writings dominate until Vesalius (1514–1564).

1490 Running heads appear for the first time in the *Philosophia Pauperum* by German scholar Albertus Magnus. This now-common device repeats a book's title or a chapter's heading at the top of successive pages of a book.

1491 First anatomical book to contain printed illustrations is German physician Johannes de Ketham's *Fasciculus Medicinae*.

1491 The first paper mill, in Poland, is built.

1492 Christopher Columbus (Cristóbal Colón; 1451–1506) discovers America and is quickly followed by Spanish and Portuguese explorers.

1492 Martin Behaim (c.1436–1507), Spanish navigator and geographer, produces the first globe map of Earth. Although it does not contain the yet-undiscovered American continent and Pacific Ocean, his globe is important as a correct method of depicting Earth and its features.

1492 Francesco Pellos (Pellizzati) publishes a work that gives us the first printed example of the decimal point.

1492 Venereal diseases, smallpox, and influenza are brought by Columbus' expedition (and subsequent European explorers) to the New World. Millions of native peoples eventually die from these diseases because of a lack of prior exposure to stimulate immunity. In some regions, whole villages were wiped out, and across broader regions, up to 95% of the native population dies as a result of exposure to these new pathogens.

1493 Christopher Columbus (1451–1506), Italian explorer, brings sheep, cattle, and hogs to the new world.

1495 Aldus Manutius (1449–1515), also known as Aldo Mannucci, or Manuzio, Italian scholar and printer, issues the *Erotomata* of Constantine Lascaris, his first dated, printed book. He later produces the first printed editions of many of the Greek and Latin classics and also originates the inexpensive "pocket-size" edition.

1496 A condensed translation of Ptolemy's work titled *Epytoma in Almagestum Ptolemaei* is published in Venice. Begun by Peurbach, who died before he could finish it, it was completed about 1462 by the German astronomer Regiomontanus (1436–1476).

c.1496 The first book to contain printing from movable type that indicates measured music is *L'art et Instruction de Bien Dancer* by Michel de Toulouze.

1499 First Greek text of the Greek physician Dioscorides, *Materia Medica*, is printed. It describes over 600 plants and their medicinal properties.

1499 Springs replace weights in clocks and make possible the invention of portable watches.

c.1500 Cathedral clocks begin to be made smaller, and "table clocks" begin to appear. They are spring-driven and are very ornate, but serve to pave the way for even smaller portable clocks or "watches."

1500 Leonardo da Vinci (1452–1519), Italian artist and scientist, states that fossils were once living organisms. He also studies the nature and characteristics of moving water and says that rivers erode valleys and deposit detritus at the mouths.

c.1500 Leonardo da Vinci (1452–1519) experiments with hydrostatics and diffraction and offers a version of the principle of inertia (which will not come until the time of Galileo). He displays an ingenious insight and ability for the possibilities of the five simple machines. He also is the first to describe capillary action (liquid crawling up the side of a tube).

c.1500 Leonardo da Vinci (1452–1519) includes in his notebooks many drawings for chemical apparatuses and also lists recipes for his artistic needs. He expresses hostility against alchemists who seek to turn ordinary metals into gold.

1500 The first use of italic type is in the *Epistola Devotissime da Sancta Catharina da Siena* printed by Aldus Manutius. Designed by Italian type designer and cutter Francesco Griffo, this type is modeled on an informal, handwritten style, and its sloping, light, and compact letter form inspires all the major roman type faces that are designed during the next three centuries.

c.1500 The major trading companies of Europe begin circulating handwritten "newsletters," which become a forerunner of the daily newspaper.

c.1500 The Incas, South American Indians who live in what is today Peru and parts of Ecuador, Chile, and Argentina, use *quipu* or knotted strings to keep accounts of taxes paid and to keep a census of the population. The quipu has a main cord, held horizontally, to which several hanging cords are attached. Knots are tied in the hanging cords at regular intervals. The shape of the knot indicates the digit that a knot represents (1,2,3 etc.), and its distance from the main cord indicates its place value (one, tens, hundreds, etc.).

1500 First successful Caesarean section operation is performed on a living subject. Jacob Nufer, whose job it is to neuter farm animals, performs this emergency surgical procedure on his wife, who not only survives but bears more children in her 77–year life span.

c.1500 Leonardo da Vinci (1452–1519) begins his serious anatomical investigations, which

he continues until the end of his life. He studies the structure of muscles and bones by dissecting cadavers. His notebooks are not published until modern times however, and his findings go unknown.

c.1500 Hieronymus Brunschwig (c.1450–c.1512) of Germany writes his *Kleines Distillierbuch.* This copiously illustrated work remains the most important book on distilling for decades.

1500 Drawings indicate that Leonardo Da Vinci (1452–1519) invented a 13-wheel counter.

1501 Aldus Manutius adopts the italic type style designed by Francesco Griffo of Bologna and uses it for the work of Virgil. This lighter, more modern type replaces the older "black letter" or gothic type.

1501 An encyclopedic collection of important works in physics, *De Expetendis et Fuiendis Rebus Opus*, by Italian mathematician and physician Giorgio Valla (c.1430–1499) is published posthumously.

1502 Camillus Leonardus (also known as Camillo Leonardi) of Italy, in his *Speculum Lapidum*, classifies minerals according to their physical characteristics and states that the identification of stones depends on their hardness, porosity, gravity, and density.

1502 Gabriele Zerbi (1468–1505), Italian anatomist, writes the first book considering the anatomy of the infant.

1502 The renowned French printing house of the Estienne family is founded.

c.1504 Peter Henlein (1480–1542), German locksmith and clockmaker also called Hele, builds the first really portable clock or "watch." This six-inch high, drum-shaped watch is spring-driven and made entirely of iron.

1504 Christopher Columbus (1451–1506) impresses and frightens a group of Native Americans by correctly predicting a total eclipse of the moon. He uses the *Ephemerides Astronomicae* of the German astronomer Regiomontanus.

1505 Filippo Beroaldo (1453–1505) of Italy publishes his *De Terremotu et Pestilentia*, a short work on earthquakes and the plague. This may be the first printed book on earthquakes.

c.1505 Leonardo da Vinci (1452–1519) makes the first wax cast of the brain ventricles (of an ox).

1505 Royal College of Surgeons is first chartered in Edinburgh.

1507 Antonio Benivieni (c.1440–1502), Italian physician, founds pathological anatomy with the posthumous publication of his book *De Abditis Nonnullis ac Mirandis Morborum et Sanitionum Causis.* In this work he explains for the first time how the dissection of cadavers can be used to study internal diseases and to determine the cause of death.

1507 Martin Waldseemüller (c.1470–c.1518), German cartographer, publishes a map that shows a new continent he names "America." He concludes that what Columbus found in 1492 was in fact an entirely unknown continent as the Italian navigator Amerigo Vespucci (1454–1512) had claimed. He names it America after Vespucci.

1507 Nicolaus Copernicus (1473–1543), Polish astronomer, begins work on his new theory of heliocentrism. Over the next seven or eight years he circulates a manuscript containing his theory to several friendly scholars.

1508 Guaiac wood is brought to Europe from newly-discovered America. Also called lignum vitae, the tree has a resin obtained by distilling its wood that is used to treat respiratory disorders.

1510 Two German books lay the foundation for industrial chemistry. *Bergwerkbüchlein* is dedicated to mineralogy and geology, and *Probierbüchlein* focuses on chemical tests and introduces quantitative concepts.

1513 Juan Ponce de León (c.1460–1521), Spanish explorer, offers the first written description of the Gulf Stream in the North Atlantic.

1513 Eucharius Roesslin (c.1490–1526) publishes his early textbook on obstetrics called *Rosengarten.* He is the first to deal with midwifery independently of surgery.

1514 First description of injuries caused by firearms is contained in Italian physician Giovanni da Vigo's (1460–1525) *Practica*

Copiosa in Arte Chirurgica. He endorses the practice of using hot oil or cautery on gunshot wounds.

1514 Johann Werner (1468–1522), German mathematician, publishes a collection of works on mathematical geography and cartography.

1515 The first printed edition of Claudius Ptolemy's *Almagest* appears in the form of a Latin translation from the Arabic. The first Latin translation made from a Greek text is published in 1528.

1515 The matchlock firearm is replaced by the wheellock or firelock musket. With this gun, the charge or powder is ignited by sparks produced when a serrated wheel is spun against iron pyrite. This eliminates the need for a burning fuse.

1516 Alessandro Achillini (1463–1512), Italian anatomist, studies the nervous system and is the first to recognize the function of the first pair of cerebral nerves. His book containing this and other anatomical discoveries is published four years after his death.

1516 The first printing press on the African continent is established at Fez, Morocco, by Jewish refugees who had worked in Lisbon, Spain, for the Rabbi Eliezer Toledano.

1517 Girolamo Fracastoro (c.1478–1553), Italian physician, says that fossils are creatures that once lived exactly where they are found.

1517 Hans von Gerssdorff (1454–1517), German military surgeon, writes a field manual for treating wounds that contains the first illustration of an amputation to appear in a machine-printed book.

1518 College of Physicians is first established in London, England.

1519 Leonardo da Vinci (1452–1519) writes his (unpublished) treatise on water in which he says that seawater rose to the mountain tops, formed rivers, and then returned to the oceans.

1520 Hops are first cultivated in England. They are used in medicine and to impart a bitter flavor to malt liquors.

c.1520 The first book printed in Africa is a handbook in Hebrew printed at Fez, Morocco, by Jewish exiles from Spain.

1520 Theophrastus Bombastus von Hohenheim Paracelsus (1493–1541), Swiss physician and alchemist, is appointed to the chair of medicine at Basel. He advocates the use of chemicals in medicine and recommends opium as a cure (naming it laudanum), as well as mercury and antimony. Among his books, *De Natura Rerum* and *Archidoxis* are of particular interest to chemistry.

1521 Cesare Cesariano, student of Italian artist and scientist Leonardo da Vinci, publishes his master's observations of the phenomenon called the camera obscura. During the Renaissance, experimenters use a dark room or chamber ("camera obscura" in Latin) to experiment with this phenomenon, thus naming it. The camera obscura becomes the direct ancestor of the modern photographic camera.

1521 First published anatomical drawings made from nature are those by Italian surgeon Giacomo Berengario da Carpi (1470–1530) in his *Commentaria*. Leonardo da Vinci's earlier excellent anatomical research and drawings were not published for centuries. The reform of anatomy begins with Carpi, who is the precursor of Vesalius.

1521 Giacomo Berengario da Carpi is the first to describe the syphenoid sinuses and the veriform appendix, as well as the first to discuss the action of cardiac valves.

1524 First hospital in the New World is erected by Spanish explorer Hernando Cortez (1485–1547) in Mexico.

1525 First modern Latin translation of Hippocrates (460–370 BC) is published in Rome, Italy.

1525 Gonzalo Hernandez de Oviedo y Valdes (1478–1557) of Spain publishes the first systematic description of the medicinal plants of Central America.

c.1525 Paracelsus (1493–1541) begins the use of mineral substances as medicines. He believes that life phenomena are chemical processes and teaches that Galen (c.129–c.216) should not be considered an authority.

1525 Philipp Ulstadt of Germany publishes *Coelum Philosophorum*, a distillation book

that adapts the hands-on techniques of the alchemists to medicine. It foreshadows the iatrochemical movement.

1526 First Greek text of Hippocrates (460–370 BC) is published in Venice, Italy.

1527 Paracelsus (1493–1541) publicly burns the writings of Galen (c.129–c.216) at Basel. He rejects the traditional medical methods as irrational, and he founds iatrochemistry, believing that the body is linked in some way to the laws of chemistry.

1530 First treatise devoted exclusively to the teeth is a collection of older teachings, *Artzney Buchlein wider allerei Kranckeyten und Gebrechen der Zeen*, published anonymously in Germany.

1530 Girolamo Fracastoro (1478–1553) writes his poem called "Syphilis" (*Syphilis sive Morbus Gallici*), which gives the definitive name to the sexually-transmitted disease that is spreading throughout Europe.

1530 Otto Brunfels (1464–1534) of Germany writes his landmark herbal titled *Herbarum Vivae Eicones ad Naturae Imitationem.* Herbalism begins to change into scientific botany with this first of the modern herbals written by one of the "German fathers of botany."

1530 Sarsaparilla, native to Mexico and Peru, is introduced to Europe.

c.1530 Paracelsus (1493–1541) writes of the occult properties of the magnet.

1532 François Rabelais (c.1494–1553), French physician and writer, publishes the first Latin version of the aphorisms of Hippocrates.

1533 Francesco Bonafide (1474–1558), Italian physician, holds the first chair of *materia medica* at Padua.

1535 Valerius Cordus (1515–1544), German physician and botanist, publishes his *Dispensatorium*, which is the first really adequate pharmacopoeia.

1535 Mariano Santo di Barletta (1490–1550), Italian physician, gives the first account of a median lithotomy, in which a surgeon makes an incision into the urinary bladder to remove a kidney stone.

1536 Ambroise Paré (1510–1590), French surgeon, makes the first exarticulation of the elbow joint. He is also the first to popularize the use of a truss for a hernia.

1536 Antonius Musa Brasavola (1500–1555), Italian physician and botanist, publishes his *Examen Omnium Simplicium Medicamentorum*, which details the herbal and metallic pharmacy of this period.

1536 Paracelsus (1493–1541) publishes his great surgical treatise, *Chirurgia Magna.* He stresses the importance of using minerals to treat diseases and by doing so, essentially founds chemotherapy.

1537 Johannes Dryander (1500–1560), German anatomist and astronomer, publishes his *Anatomicae...Corporis Humani Dissectionis.* It is one of the first books to offer illustrations made directly from dissecting human cadavers.

1537 The medieval translation of the work of the Arabian astronomer Albategnius (c.858–929) is published as *De Motu Stellarum.*

1537 Niccolo Tartaglia (1499–1557), Italian mathematician, publishes *La Nouva Scientia*, which is the first book written on the theory of projectiles or ballistics. He believes incorrectly that a cannon ball falls straight downward after being propelled forward.

1537 Ambroise Paré (c.1510–1590) documents the techniques of manipulation used to turn the fetus in the womb and control entry into the birth canal.

1537 Ambroise Paré (c.1510–1590) revives the use of ligature to treat gunshot wounds, replacing cautery of the wounds.

1538 Girolamo Fracastoro (1478–1553) publishes his *Homocentricorum*, in which he revives the homocentric sphere theory of the Greek Eudoxus. He also discusses comets and notes that they have a tail.

1539 Alessandro Piccolomini (1508–1579) of Italy publishes his *Della Sfera del Mondo.* The appendix contains a simplified chart of the heavens, making Piccolomini the first to label the stars with letters. He omits the traditional pictorial representations and the fainter stars and concentrates on making the bright ones identifiable and

easy to find. This method is first adopted by the German astronomer Johann Bayer (1572–1625).

1539 Martin Luther (1483–1546), German Reformation leader, reacts to the unpublished Copernican manuscript that contains his new theory of heliocentrism. He calls the astronomer a "madman" who "wants to overturn the entire art of astronomy" by going against Holy Scripture.

1540 Georg Rheticus (1514–1574), German mathematician, publishes his *Narratio Prima*, which is the first printed announcement of the work of Nicholaus Copernicus (1473–1543). As the first disciple of Copernicus, he had visited the Polish astronomer in 1539, and it was through his urging that Copernicus finally allowed his work to be published.

1540 Giovanni Ventura Rosetti writes his *Plictho dell'arte de Tentori*, the first book on dyeing fibers and fabrics.

1540 Thomas Raynalde of England publishes *The Byrthe of Mankind*. This obstetrical work is based on Eucharius Roesslin's *Der Swangen Frawen und Hebammen Rosegarten*, first published in Germany in 1513.

1540 Vannuccio Biringuccio (1480–c.1539) of Italy publishes his *De La Pirotechnia* in Venice. This original work is the first of its kind, in that it concentrates solely on metallurgy. It also offers the first description of the amalgamation process used to extract silver from its ores.

1540 Peter Apian (1495–1552), German astronomer, publishes his *Astronomicum Caesareum*, which contains his pioneering observations on comets. His illustrations of comets show their tails always pointing away from the sun.

1540 Servetus offers the first description of the pulmonary circulation of blood.

1540 Valerius Cordus (1515-1544), German physician, provides the first written description of how to prepare ether.

1541 Giovanni Battista Canano (1515–1579), Italian anatomist, publishes his *Musculorum Humani Corporis Picturata Dissectio* in Ferrara, Italy. This work is one of the first anatomical books to be illustrated with copperplate engravings, which offer finer and more delicate detailing than earlier methods.

1542 Leonhard Fuchs (1501–1566), German botanist, publishes his pioneering botanical work, *De Historia Stirpium*, which contains realistic illustrations of plants.

1542 Alvar Nunez Cabeza de Vaca (c.1490–c.1560), Spanish explorer, first describes a "black drink" made from a holly bush that is used as a purgative by Native Americans in southeastern America in his book, *La Relacion y Commentarios.*

1542 Bubonic plague from China devastates Constantinople before going on to kill millions across Europe.

1543 Andreas Vesalius (1514–1564), Dutch anatomist, publishes his *De Corporis Humani Corporis Fabrica*, the first accurate book on human anatomy. Its illustrations are of the highest level of both realism and art, and the result is a masterpiece that revolutionizes biology and ranks as one of the most influential medical works ever written.

1543 Niccolo Tartaglia (1499–1557), Italian mathematician, publishes the first Latin translation of several previously little-known works by Archimedes such as the famous treatise on floating bodies.

1543 Nicolaus Copernicus (1473–1543), Polish astronomer, publishes his *De Revolutionibus Orbium*, in which he proposes a heliocentric or sun-centered universe. This unpopular book was banned by the Catholic Church for having removed Earth and therefore mankind from the center of the universe. Nonetheless, it as much as any single publication can be said to mark the beginning of the Scientific Revolution.

1543 Peter Ramus (1515–1572), French scholar also called Pierre de la Ramee, writes his *Animadversions on Aristotle*, in which he attacks Aristotle's physics. He is later forbidden by the Church to teach or write against Aristotle and is threatened with torture.

1544 Georg Hartmann (1489–1564), German physicist, describes the magnetic dip,

noting that a magnetic needle is not perfectly horizontal while pointing north.

1544 Girolamo Cardano (1501–1576), Italian mathematician, publishes his *De subtilitate*, in which he discusses motion and mechanics as well as ballistics and magnetism.

1545 Francesco Bonafide (1474–1558), Italian physician, founds the first botanical garden in Europe in Padua, Italy. It is affiliated with the university medical school.

1545 Charles Estienne publishes illustrations depicting the circulatory and nervous systems.

1546 Georg Bauer, better known as Georgius Agricola (1494–1555), German mineralogist, publishes his *De Natura Fossilium*, in which he classifies minerals and other earth materials. This is probably the first mineral classification that is really empirically-based, and it offers a comprehensive system. It is also the first handbook on mineralogy.

1546 Georgius Agricola (1494–1555), German mineralogist, publishes his *De Ortu et Causis Subterraneorum*, in which he considers the origins of mountains. He argues there are many factors in mountain-building, but the main mechanism is erosion, caused by moving water, with mountains forming along the banks of ever-deepening river beds.

1546 Girolamo Fracastoro (1478–1553), Italian physician, writes his *De Contagione et Contagiosis Morbis*, which contains new ideas on the transmission of contagious diseases and is now considered the real scientific beginning of that study.

1546 Gerardus Mercator (1512–1594) describes Earth's magnetic poles.

1547 Portuguese sailors bring the first orange tree from China to Europe.

1549 Philip Melanchthon (1497–1560), German humanist and religious reformer, publishes his *Initia Doctrinae Physicae*, in which he accuses Nicholaus Copernicus (1473–1543) of vanity for seeking to be different at any cost and also of copying the idea of heliocentrism from the Greek Aristarchus.

1550 Girolamo Cardano (1501–1576), Italian mathematician, publishes his *De Subtilitate* and seven years later *De Rerum Varietate*. Although primarily on other subjects, both are of interest to chemistry as Cardano denies the Aristotelian element of fire, which he says is not a substance like the other three. He also offers two criteria for metals: They can be melted and they will harden upon cooling.

1550 Girolamo Cardano (1501–1576), Italian mathematician, uses the measurement of parallax to prove that comets are not a phenomenon within Earth's atmosphere.

1550 Hans Lobsinger of Germany devises the wooden box bellows. This improvement of the old leather bellows increases the production of iron via the use of blast furnaces.

1551 Erasmus Reinhold (1511–1553), German mathematician, calculates and publishes his *Tabulae Prutenicae*, the first set of planetary tables based on Copernician theory.

1551 Konrad von Gesner (1516–1565), Swiss naturalist, publishes the first of his five-volume (1551–1557) *Historia Animalium*, which marks the border between the ancient and modern methods of studying animal life.

1551 Robert Recorde (1510–1558), English mathematician, publishes his *Pathwaie to Knowledge*, which alludes to Copernican theory and contains the first published recognition of that system in England.

1551 Gabriello Fallopio (1523–1562), Italian anatomist, succeeds Vesalius to the chair of anatomy at Padua, Italy. He describes the inner ear and the tubes that lead the human ovum from the ovary to the uterus (now called Fallopian tubes).

c.1552 Bartolomeo Eustachio (1524–1574), Italian anatomist, discovers the narrow canal connecting the ear and the throat ("Eustachian tubes"). He is also the first to describe the adrenal glands and pioneers the study of the detailed structure of teeth.

1552 Edward Wotten (1492–1555), English physician and naturalist, publishes his *De Differentiis Animalium*; his whose systematic comparison and classification of animals represents a turning point in zoology.

1552 Konrad Gesner (1516–1565), in his *Opera Botanica and Historia Plantarum*, sets forth taxonomic differences between genus, species, etc.

1553 Publication of *On the Restoration of Christianity* by the Spanish theologian and naturalist Michael Servetus (1511–1553). In this work, Servetus describes pulmonary circulation. Persecuted by the Catholic Inquisition, Servetus is ultimately arrested and burned at the stake.

1553 French naturalist Pierre Belon's (1517–1564) *De Aquatilibus* advances the study of marine animals and observes that, like humans, fetal porpoises are attached via an umbilical cord to a placenta.

1554 Jean-François Fernel (1497–1558), French physician, gives "physiology" its modern meaning.

1554 Pietro Andrea Mattioli (1500–1577) of Italy publishes the most famous and highly successful commentary on Dioscorides' *Materia Medica* at the time.

1554 Guillaume Rondelet (1507–1566) of France publishes his illustrated work on marine animals. This pioneering work remains influential for over a century and is titled *Libri de Piscibus Marinis.*

1554 Girolamo Cardano, (1501–1576), Italian mathematician, in *De Subtiltate*, argues that nothing has perpetual motion.

1555 Olaus Magnus (1490–1557), Archbishop of Uppsala, Sweden, writes his *Historia de Gentibus Septentrionalibus*, in which he offers the idea that the bottom of the ocean follows a course that is linked to the land above the sea.

1555 Pierre Belon (1517–1564), French naturalist, publishes his *L'Histoire de la Nature des Oyseaux*, in which he first depicts the homologies between the skeleton of a bird and a human. This illustrates the very early beginning of comparative anatomy.

1555 Geronimo Ruscelli of Italy publishes *Secreti* in Venice under a different name. This compilation of chemical recipes has phenomenal success and sees more than 90 editions in virtually every European language.

1556 Georgius Agricola (1494–1555), German mineralogist, publishes his *De Re Metallica.* Actually published a year after his death, this monumental work summarizes every aspect of mining and metallurgical processes to his time. It has 273 woodcuts that illustrate machines and processes, and it took him twenty-five years to complete. As the product of a lifetime of practical experience, it contains little speculation, although he does offer the concept that varying proportions of earth, air, fire, and water account for the differences in the external characteristics of minerals.

1556 Georgius Agricola (1494–1555), in *De Re Metallica*, classifies minerals and observed physical geography.

1557 John Field of England publishes his *Iuxta Copernici et Reinholdi Canona*, in which he supports the heliocentric theory of Nicholaus Copernicus.

1557 Julius Caesar Scaliger (1484–1558), Italian scholar, writes his *Exercitationes Exotericae de Subtilitate*, in which he makes the first specific reference to platinum as a noble metal with refractory qualities found in Central America.

1558 Matteo Realdo Colombo (1516–1559), Italian anatomist, is the first to use living animals in laboratory experiments (especially to study the function of the heart and lungs). He is also the first to mention the folding of the peritoneum and the first to describe the mediastinum (the mass of tissue and organs separating the two lungs).

1559 Matteo Realdo Colombo (1516–1559), Italian anatomist, publishes his *De Re Anatomica* in Venice. Strongly influenced by Vesalius, this work contains Colombo's discovery of the lesser (pulmonary) circulation of the blood.

1560 Jean Nicot de Villemain (1530–1600), French ambassador to Portugal, sends tobacco seeds from the New World to Paris and introduces tobacco into France and the rest of Europe. Tobacco is already being smoked in Portugal and Spain.

c.1561 Gabriel Fallopio (1523–1562), Italian anatomist, discovers the tubes ("Fallopian

tubes") that lead the human egg or ovum from the ovary, where it is formed, to the uterus where, if it is fertilized, the embryo develops. He also describes the inner ear and incompletely describes the cranial nerves.

1561 Wilhelm IV (1532–1592), Landgrave (Count) of Hesse (Germany), builds a private astronomical observatory in order to pursue his own interests in astronomy. This is the first observatory to have a rotating dome. He also befriends the Danish astronomer Tycho Brahe (1546–1601).

1561 Valerio Faenzi of Italy publishes *De Montium Origine*, which may be the first printed book in Europe dealing with the origin of mountains.

1562 Bartolomeo Eustachio (1524–1574), Italian anatomist, is appointed professor of medicine in the Collegio della Sapienza in Rome, Italy. He discovers the narrow canal connecting the ear and the throat, which becomes known as the Eustachian tube.

1562 Johann Mathesius (1504–1565), German theologian, writes in his *Sarepta* that heavy metals in Earth formed as a soft plastic which then hardened.

1563 Bartolomeo Eustachio (1524–1574), Italian anatomist, publishes his book on teeth, *Libellus de Dentibus*, in which it is stated for the first time that the second teeth have their own dental sac and do not originate, as Vesalius believed, from the roots of the milk teeth.

1563 Garcia da Orta (c.1500–c.1568), Portuguese botanist, compiles the first good compendium on the *materia medica* of Native Americans, as well as the first European manual on tropical medicine.

1563 Johann Weyer (1555–1588) writes his *De Praestigiis Daemonum*, in which he gives a rational explanation of several medical phenomena usually attributed to magic and witches.

1563 Bernard Palissy (c.1510–1589), French potter, publishes his *Recette Veritable*, in which he discusses agriculture, geology, mining, and forestry. He discovers the Italian secret of producing majolica (pottery decorated with an opaque tin glaze) and is considered one of the most eminent chemists in France.

1564 Ambroise Paré (1510–1590), French surgeon, publishes his major work on surgery and so profoundly influences this new discipline that he has become known as the father of modern surgery.

1564 Gabriel Fallopio (1523–1562), Italian anatomist, writes in his *De Medicatis Aquis atque de Fossilibus* that water from the oceans descends into the earth, is evaporated by fire, and then rises to the surface where it is condensed as spring water since its salt has been deposited below.

1564 Arantius asserts that there is no direct connection between fetal and maternal vascular systems but that they are brought into close contact in the placenta.

1565 Johannes Kentmann (1518–1574), German geologist, publishes his *Calculorum qui in Corpore ac Membris Hominum*, which comprises the first catalog of a geological collection based on Agricola's classification.

1565 Konrad Gesner (1516–1565) publishes his *De Rerum Fossilium*, which contains the first illustrations of fossils. He does not however, consider them to be the remnants of past living organisms. He classifies minerals into fifteen categories.

1566 Guillaume Rondelet (1507–1566), French naturalist and physician, builds the first anatomy amphitheater in Rome, Italy. This facility allows the observing students to surround the instructor.

1567 A book on miner's tuberculosis by Swiss physician and alchemist Paracelsus (1493–1541) is posthumously published.

1568 Italian physician Constanzo Varolio (1543–1575) makes available to other scholars his independent studies of the structure of the human brain.

1568 Zacharias and Hans Janssen develop the first compound microscope. The innovation opens new opportunities for the study of structural detail.

1569 Nicolas Monardes (1493–1588) of Spain first describes "Sassafras," given to him and named by a Frenchman from Florida.

1569 Pierre de la Ramé (1515–1572), French philosopher also known as Petrus Ramus), publishes his *Scholarum Mathematicarum*, in which he is the first to maintain the need for a radical reform of astronomy. He then goes on to praise and support the theory of Copernicus.

1571 Augustinus Galesius of Italy publishes in Bologna, Italy, his *Terra Motu*, in which he describes the various movements of the earth during an earthquake.

1572 First significant Latin translation of the work of Greek astronomer Aristarchus (c.320–250 BC) is published as *De Magnitudinibus, et Distantis Solis, et Lunae.*

1572 Tycho Brahe (1546–1601), Danish astronomer, notices a dramatic new star in the night sky near Cassiopeia. This is not really a new star but rather a supernova or exploding star.

1573 Costanzo Varolio (1543–1575), Italian anatomist, illustrates the pons, a part of the brain's stem that Flemish anatomist Andreas Vesalius had not seen.

1573 Tycho Brahe (1546–1601), Danish astronomer, publishes his *De Nova Stella*, in which he records his observations of the galactic supernova he had observed the year before. This exploding star glowed brighter than Venus before fading away after a year and a half. Since this book, any exploding star is called a nova. It also put to rest the long-held but incorrect Aristotelian notion that the heavens are perfect and unchanging.

1574 Michele Mercati (1541–1593), Italian naturalist and physician, writes in his *Metallotheca Vaticana* that fossil fishes are caused by radiation from space. His book is not published until 1717.

1574 Lazarus Ercker (c.1530–1594) of Germany publishes his *Beschreibung aller Furnemisten Mineralischen Ertzt und Bergkwercks Arten*, which is the first manual of analytical, metallurgical chemistry. His text is especially valuable to the practicing assayer.

1574 Tycho Brahe (1546–1601), Danish astronomer, argues in *De mundi aetherii recentioribus phaenomenis* that a comet he discovered lies beyond the moon.

1575 Jacques-Albert Aubert, French chemist and physician, publishes his *De Metallorum Ortu et Causis*, in which he states that metals are alive and do not grow from seeds as many believe.

1575 Juan Huarte de San Juan (c.1530–1592), Spanish physician, publishes his *Exemen de Ingenios para Las Ciencias*, which becomes the first modern attempt at systematically studying the functions of the brain and establishing a link between psychology and physiology.

1576 Charles de L'Ecluse (1526–1609) of France publishes his *Rariorum Aliquot Stirpium per Hispanas Observatarum Historia*, which is the first book on Spanish flora. It is also the first book to contain information on the tulip, which he introduces into Europe from Turkey.

1576 Thomas Digges (c.1543–1595), English mathematician and astronomer, publishes *A Perfit Description of the Coelestiall Orbes*, in which he offers the first complete and original exposition of the Copernican system. His work even contains illustrations.

1576 Tycho Brahe (1546–1601), Danish astronomer, assembles his great catalog of the stars. This establishes his reputation as the greatest naked-eye astronomer and as the founder of modern observational astronomy.

1576 Luigi Lilio of Italy completes his *Compendium Novae Rationis Restituendi Kalendarium*, which solves the problem of the gradual shifting date of Easter. His suggested plan for calendar reform is eventually accepted by the Church.

1576 Tycho Brahe (1546–1601), Danish astronomer, constructs a planetary observatory to accurately record motions of celestial bodies.

1578 Michael Maestlin (1550–1631), German astronomer and teacher of Johannes Kepler (1571–1630), announces his acceptance of Copernican theory.

1580 Bernard Palissy (c.1510–1590), French potter, publishes his *Discours Admirables*

de la Nature des Eauxes et Fonteines, in which he discusses the origins of petrified wood and fossil fish. Noticing that many fossil conchylia are identical to living mollusks, he concludes that the areas in which they are found must have been submerged at one time.

1580 King Frederick II of Denmark (1534–1588) builds an astronomical observatory on the island of Hveen (between Denmark and Sweden) for Danish astronomer Tycho Brahe.

1580 Prospero Alpino (1553–1617), Italian physician, first brings coffee into Italy.

1580 The Italian named Maffei first brings tea into Italy.

1580 Thomas Twyne (1543–1613) of England publishes his book *Concerning the...Effects of All Earthquakes*, which is the first work in English to deal solely with earthquakes.

1581 François Rousset (1535–c.1590) publishes his *Traité Nouveau de L'Hystérotomotokie*, which is the first treatise devoted to the Caesarean section.

1581 Galileo Galilei (1564–1642), Italian astronomer and physicist, discovers the principle of isochronism or the regularity of the pendulum. His experiments show the youthful Galileo that a pendulum swings in constant time, irrespective of the width of its swing.

1581 Robert Norman, English navigator and instrument maker, publishes *The Newe Attractive*, documenting his research on magnetism. He discusses the known properties of the magnet and is the first to note that steel does not gain in weight when magnetized (dispelling the notion that magnetism is a real fluid). Also, he is the first to describe the phenomenon of "magnetic dip," as he suspends a compass needle to allow vertical movement and notes that it points down toward the earth. This is later used by William Gilbert (1544–1603).

1582 Pope Gregory XIII (1502–1585) accepts Luigi Lilio's suggested plan for calendar reform and introduces what becomes known as the Gregorian calendar to replace the Julian calendar. In order to make the transition, Gregory simply orders ten days eliminated (October 5–14) and adjusts the old calendar to the much more workable new one.

1583 Andreas Cesalpino (1524–1603), Italian physician also called Cesalpinus, writes his *De Plantis*. It is considered by most to be the first real scientific textbook on botany in that it defines the basic criteria of botanical taxonomy.

1583 George Bartisch (c.1535–1607), German surgeon, publishes his *Ophthalmodoueia*, which is a complete summary of Renaissance eye surgery.

1584 Giordano Bruno (1548–1600), Italian philosopher, begins writing on his new view of the universe. Using Copernican ideas, he becomes the first to connect his system with what becomes a truly revolutionary interpretation of the universe. He expounds on the infinity of space and the habitability of other worlds, among other things. He is charged with heresy and arrested by the Inquisition in 1592. He refuses to recant any of his ideas and is burned alive in Rome, Italy, 16 years later.

1584 Giordano Bruno (1548–1600), Italian philosopher, writes that there never was a great flood but only local ones. He also says that there have been many frequent alterations in Earth's topography, and that the oceans are deeper than the mountains are high.

1584 In Moscow, the Kamennyj Prizak is founded as an organization for identifying and exploiting natural resources.

1584 Sir Walter Raleigh (1554–1618), English explorer, brings curare from Guiana. Obtained from a plant, this drug is a skeletal-muscle relaxant belonging to the alkaloid family. It can be used to paralyze.

1584 Giordano Bruno (1548–1600), Italian philosopher, argues that stars are suns with other planets.

1585 Giambattista Benedetti (1530–1590), Italian physician and mathematician, publishes his *Diversarum Speculationum Mathematicarum et Physicarum*, in which he makes major contributions to the mathematization of mechanics and the theory of impetus.

1586 Andrej Cohov makes a 40-ton cannon, the largest such gun of its time.

1586 Blaise de Vigenere (1523–1596), French humanist, proposes a creative way of communicating over a stone wall by passing a lodestone over the appropriate letters that circumscribe a compass needle.

1586 Galileo Galilei (1564–1642), Italian astronomer and physicist, writes his *La Bilancetta*. In this unpublished treatise on hydrostatics, he analyzes how to determine the compositional purity of a substance and suggests an improved hydrostatic balance.

1586 Marcello Donati (c.1538–1602) of Italy gives the first description of a gastric ulcer.

1586 Thomas Harriot (1560–1621) of England first takes potatoes from America to Sir Walter Raleigh's (c.1552–1618) Irish estate.

1586 Simon Stevin (1548–1620), Dutch mathematician also called Stevinus, conducts experiments that refute the Aristotelian doctrine that heavy bodies fall faster than light ones. He also founds hydrostatics by demonstrating that the pressure on a liquid varies according to how high above Earth's surface it is and not upon the shape of the container that holds it. His demonstrations also eliminate many standard arguments in favor of the existence of perpetual motion.

c.1586 Galileo Galilei (1564–1642), Italian astronomer and physicist, writes a treatise on gravity titled *De motu gravium*.

1587 Giulio Cesare Aranzio (1530–1589), Italian anatomist, gives the first description of a deformed pelvis.

1587 Galileo Galilei (1564–1642), Italian astronomer and physicist, begins experiments that lead to his law of falling bodies. He uses a gently-sloping inclined plane and shows that the rate of fall of a body is independent of its weight. He eventually states correctly that all objects will fall at the same rate in a vacuum. He also shows that a body can move under the influence of two forces at one time.

1588 Thomas Harriot (1560–1621) of England publishes *A Briefe and Tru Report of the New Found Land of Virginia* in London. This is the first book in vernacular English that is devoted to the flora and fauna of America.

1589 Giambattista della Porta (1535–1615) of Italy publishes an enlarged version of his *Magia Naturalis*, which he first published in 1558. In this edition he offers practical, theoretical, and experimental sections on optics and magnetism.

1589 Giambattista della Porta (1535–1615), Italian physicist, publishes the enlarged edition of his *Magiae Naturalis*. He tells, among other things, how to prepare sulfuric acid and gives details on various laboratory apparatus.

c.1590 First compound microscopes are made by Dutch optician Zacharias Janssen (1580–c.1638). No record exists of Jannsen actually using his multiple-lens microscope.

1590 Jose de Acosta (1539–1600), Spanish theologian and explorer, publishes his classic account of the natural history of the New World (South America), *Historia Natural y Moral de las Indias*. It is the earliest known survey of the New World and its relation to the old. He speculates that Indians populated the New World by migrating over a land bridge that formerly connected Asia and North America.

1591 Thomas Harriot (1560–1621), English mathematician, is the first Westerner to note that snowflakes are hexagonal (six-sided). He does not publish his findings. The Chinese however, document snowflake crystal shapes from the second century BC.

1591 Thomas Harriot (1560–1621) calculates the angular distance between the celestial north pole and Polaris, the North Star.

1592 Galileo Galilei (1564–1642), Italian astronomer and physicist, is appointed to the faculty of the University of Padua in Italy. His conversion to the new Copernican theory of heliocentrism dates to this period.

1592 Galileo Galilei (1564–1642), Italian astronomer and physicist, develops the first thermometer. He warms an empty bulb that has a tube extending from it into a container of water. As the warm air in the

bulb cools, it contracts and draws water into the tube. As the water level rises or falls, Galileo is able to judge but not measure the temperature with the very crude device.

1592 Prospero Alpini (1553–1617), Italian physician, publishes his *De Plantis Aegypti*, which is the first treatise on the plants of Egypt. Having lived in Egypt for three years, Alpini introduces exotic plants to Europe upon his return.

1592 Galileo Galilei (1564–1642), Italian astronomer and physicist, argues that the physical laws of the cosmos are the same as those on Earth.

c.1592 Galileo Galilei (1564–1642), Italian astronomer and physicist, demonstrates that that the path of a projectile is a parabola.

1593 Giambattista della Porta (1535–1615) of Italy publishes his *De refractione optices*, in which he describes the properties of refracting lenses, studies binocular vision, and compares the pupil of the eye to the lens of a camera obscura.

1595 Andreas Libavius (1560–1616), German alchemist, publishes his *Alchymia* in Frankfurt, Germany. Most now consider it to be the first chemical textbook. Libavius is convinced totally of the significance of chemistry to medicine.

1595 Gerardus Mercator (1512–1594), Flemish geographer, has his book of maps, titled *Atlas, sive Cosmographicae*, published posthumously. The book's cover depicts the Greek Titan, Atlas, holding the world on his shoulders, and ever since, all future books of maps are called "atlases."

1595 Geronimo (Scipione) Mercurio (1540–1616), Italian physician, publishes what becomes one of the most celebrated medical books of the Renaissance. His book on obstetrics, *La Comare O Raccoglitrice*, is republished in scores of editions into the eighteenth century.

1595 David Fabricius (1564–1617), German astronomer, first observes a star of the third magnitude that disappears when he next looks for it in October. He never learns that it is a star that has periodic variations in brightness. Later named Omicron Ceti, it is the first variable star to be discovered.

1596 Andrea Cesalpino, (1519–1603), Italian botanist also called Andreas Cesalpinus, writes in his *De Metallica* that fossils are the remains of once-living creatures left behind by the sea that were petrified by the influence of rocks.

1596 Johannes Kepler (1571–1630), German astronomer, publishes his *Mysterium Cosmographicum*, the first important work in astronomy that supports the Copernican theory.

1596 Tycho Brahe (1546–1601), Danish astronomer, discovers the variation in the obliquity of the ecliptic. The ecliptic is the apparent path of the sun among the stars (or through the zodiac). The obliquity is the angle of Earth's axis to the plane of the sun's apparent motion in the sky.

1597 Gasparo Tagliacozzi (1545–1599), Italian surgeon, performs rhinoplasty or plastic surgery of the nose. Although rhinoplasty was known to the ancient Hindus, it is Tagliacozzi who practices this surgery based on solid anatomical knowledge, and it is he who writes the first book about it.

1597 John Gerard (1545–1612), English botanist, publishes his *The Herball or Generall Historie of Plantes*, which becomes the best-known and most often-quoted herbal in the English language.

1597 *Alchemia*, the first textbook on chemistry, is written by the German alchemist Andreas Libavius (c.1540-1616). He is also the first to describe the preparation of hydrochloric acid and is credited with planning the first true chemical laboratory.

1598 Carlo Ruini (c.1530–1598) of Italy publishes his treatise on the anatomy and diseases of the horse, *Anatomia del Cavallo*, and founds veterinary medicine. This is also the first book dedicated entirely to the anatomical structure of a non-human creature.

1598 Tycho Brahe (1546–1601), Danish astronomer, publishes his *Astronomicae Instauratae Mechanica*, in which he offers

descriptions of his many astronomical instruments. The largest is his 19-foot quadrant.

1599 Ferrante Imperato (c.1550–1531), Italian pharmacist, writes his *Dell'Historia Naturale*, in which he states the idea that minerals vegetate and grow.

1599 Ulisse Aldrovandi (1522–1605), Italian naturalist, publishes his three-volume work on birds.

c.1600 Guidobaldo Dal Monte (1545–1607), Italian astronomer and mathematician, popularizes the statics of Archimedes.

1600 William Gilbert (1544–1603), English physician and physicist, publishes his *De Magnete*, which is a full account of his extensive investigations on magnetic bodies and electrical attraction. He suggests that Earth itself is a great, round magnet made largely of iron, and he attributes the daily rotation of Earth to magnetic forces. He is the first to use the terms electric attraction, electrical force, and magnetic pole. In this major scientific work, which is one of the earliest based on actual experimentation, he describes his experiments with his magnetized model of Earth called a "terrella."

c.1600 Invention of the first practical obstetrical forceps occurs sometime during this period and is credited to a member of the Chamberlen family. This tool, which consists of two metal blades joined together at the handle crossing, is used to deliver a child in difficult births. It is known to have been suggested by Pierre Franco of France in 1561, and it is believed that William Chamberlen (c.1540–1596) took the secret of its design with him when he fled to England from France in 1576. Both of his sons were named Peter, and it is one of them who is most often credited with the invention. The family kept the forceps a closely guarded secret for more than a century.

c.1601 Accademia dei Lincei (The Academy of the Lynx) is founded by Italian Duke Frederico Cesi (1585–1630), in Rome. Although short-lived, this is the first true scientific society. Its members include Galileo and Giambattista Della Porta.

1602 Felix Platter (1536–1614), Swiss anatomist, publishes his *Praxis Medica*, which is the first modern attempt at the classification of diseases.

1602 The first operation to remove a foreign body from the stomach is performed by Florian Mathis.

1602 Johannes Kepler (1571–1630), German astronomer, edits the unpublished work of German astronomer Tycho Brahe (1546–1601). Titled *Astronomiae Instauratae Progymnasmata*, it offers the accurate locations of 777 stars as well as significant other planetary information.

1602 The writings of Basilius Valentinus, an early 15th-century Alsatian Benedictine monk, become available with the publication of his *De Microcosmo.* This and his other works, *Currus Triumphalis Antimonii* and *Les Douze Clefs de Philosophie*, illustrate the good and bad side of chemistry at this time. His work is rich in observational detail but intertwined with mysticism as well.

1602 Ulisse Aldrovandi (1522–1605), Italian naturalist, publishes his illustrated book on insects.

1603 Andrea Bacci (1550–1598), Italian physician, states in his posthumously-published book, *De Gemmis et Lapidibus Pretiosis*, that gold and precious gems are formed when the stars focus their heavenly powers on Earth.

1603 Hieronymous Fabricius (also known as Girolamo Fabrizzi or Fabrizo d'Aquapendente; 1537–1619), Italian anatomist and physician, discovers the one-way valve in veins but does not realize its significance.

1603 Nicholas Guibert (c.1547–1620), French alchemist, publishes his *Alchymia* which, despite its title, denies the possibility of transforming metals. At this time, the words "alchemy" and "chemistry" are almost interchangeable.

1603 Ulisse Aldrovandi (1522–1605), Italian naturalist, uses the word "geology" in one

form of its modern sense, meaning the materials or rocks of the science.

1603 Johann Bayer (1572–1625), German astronomer, publishes *Uranometria*, the first edition of his catalog of the heavens. It is the first catalog to show the entire celestial sphere and describes constellations and locates more stars than even Tycho Brahe had done. More important, Bayer lists the stars of each constellation by Greek letters in order of brightness. This systematic naming device has been kept to today.

1604 Hieronymous Fabricius (also known as Girolamo Fabrizzi or Fabrizo d'Aquapendente; 1537–I619), Italian anatomist, shows the stages in the development of a chicken embryo in his *De Formato Foetu*. This work also studies the comparative morphology of the fetus in man and other animals.

1604 Johannes Kepler (1571–1630), German astronomer, publishes his book *Ad Vitellionem, Paralipomena*, in which he discusses the work of Witelo and reestablishes the importance of optics. He describes for the first time how the retina is essential to sight. He also details the part the lens plays in refraction, and that myopia is caused by the convergence of luminous rays before they reach the retina. In a later work (*Dioptrica*, 1637), he compares the eye to a camera obscura.

1604 Galileo Galilei (1564–1642), Italian astronomer and physicist, observes that the distance between a falling object and its point of departure increases as square of time.

1604 German astronomer Johannes Kepler (1571–1630) and other astronomers record a supernova in the constellation Serpens, which shines as brightly as Venus. The phenomena lasts for just over a year.

1605 Simon Stevin (1548–1620), Dutch mathematician also called Stevinus states that Earth's surface is constantly being transformed.

1605 Ulisse Aldrovandi (1522–I605), Italian naturalist, classifies minerals in his *Musaeum Metallicum*. It is not published until 1648.

1607 Edward Topsell (1572–c.1625), English naturalist, publishes *The Historie of Foure-Footed Beastes and Serpents*. Taken largely from Konrad Gesner's major work, this is the first significant treatise on zoology published in English.

1609 Johannes Kepler (1571–1630), German astronomer, theorizes that a force of gravity exists that can exert itself through empty space, and that its strength is related to the size of the bodies involved.

1609 Anselmus Boëthius de Boodt (c.1550–1632), Dutch physician, publishes his *Gemmarum et Lapidum Historia*, in which he makes one of the first attempts at a systematic description of minerals. He also classifies minerals, speculates on the nature of coral, and argues that gems have no magical powers.

1609 Galileo Galilei (1564–1642), Italian astronomer and physicist, hears a description of the Lippershey refracting telescope and constructs his own, more powerful version to study the skies. He later describes the surface of the moon, the phases of Venus, and the four satellites of Jupiter. With Galileo, the age of telescopic astronomy begins.

1609 Jalap is brought from Mexico to Europe. The root of this plant from the Morning Glory family acts as a purgative when taken in powdered form.

1609 Johann Hartmann (1568–1631), Bavarian mathematician and iatrochemist, is nominated professor of "chymiatria" at Marburg and is thus considered to be the first professor of chemistry in Europe.

1609 Johannes Kepler (1571–1630), German astronomer, publishes his *Astronomia Nova*. In this work he states his two laws of planetary motion. The first states that the orbits of the planets can be drawn as ellipses, with the sun always at one of their foci. The second says that a line connecting a planet and the sun will sweep over equal areas in equal times as the planet moves about its orbit. In other words, a planet will move faster the closer it is to the sun, and this can be determined by a rule that

can be calculated. Kepler's work put an end to the idea of the planetary orbits as perfect circles, held long since the Greeks; this becomes the cornerstone of modern astronomy.

1609 Louise Bourgeois (1563–1636), French midwife, publishes her book on obstetrics and gynecology. She becomes one of the most famous midwives, attending the French aristocracy and delivering the future king, Louis XIII, who she is said to have saved from asphyxia.

1609 Thomas Harriot (1560–1621), English mathematician and astronomer, builds a telescope contemporaneously with Galileo and studies the heavens. He compiles a map of the moon based on his telescopic observations but does not publish it.

1609 In 1609, Johannes Kepler (1571–1630), in *De Motibus Stella Martis*, publishes the results of Tycho Brahe's calculations of Mars's orbit, which were inconsistent with then-current assumption that it was circular.

1610 The first chemistry textbook in French is *Tyrocinium Chymicum*, written by French chemist Jean Beguin (c.1550–c.1620) and published in Paris. He is also the first to mention obtaining acetone by distilling lead acetate.

1610 Galileo Galilei (1564–1642), Italian astronomer and physicist, adjusts his newly-built telescope in reverse and uses it as a compound (two-lens) microscope.

1610 Galileo Galilei (1564–1642) observes moons of Jupiter.

1610 Galileo Galilei (1564–1642), Italian astronomer and physicist, publishes his *Siderius Nuncius*, which gives an account of the first use of the telescope in astronomy and tells of the discoveries he made with it.

1611 Johannes Kepler (1571–1630), German astronomer, publishes his *Dioptrice*, which founds the science of modern optics. He studies the newly-invented telescope and works on the manner in which light waves are refracted by lenses, eventually describing the laws of refraction.

1611 Johannes Kepler (1571–1630), German astronomer, publishes the first description of the hexagonal nature of snowflakes.

1611 Caspar Bartholin (1585–1629), Danish physician, publishes an anatomical manual in which he is the first to describe the olfactory nerve (associated with the sense of smell) as the first cranial nerve.

1611 Christoph Scheiner (1575–1650), German astronomer, observes sunspots on a projection of the sun's disc. He describes them as small planets that circle the sun, but is attacked by Galileo who not only claims (correctly) that the spots are on the sun's surface, but also that he saw them first.

1612 Galileo Galilei (1564–1642), Italian astronomer and physicist, publishes his *Discorso Intorno Alle Cose Che Stanno in su L'Acqua*, in which he explores hydrostatics and works out the conditions for the flotation of solid bodies in a liquid.

1612 First book on glassmaking is Antonio Neri's *L'Arte Vetraria* published in Florence, Italy.

1612 Simon Marius (1570–1624), German astronomer also called Mayr, becomes the first astronomer to mention the Andromeda Nebula, the most distant object that can be seen without a telescope. Marius also achieves fame of a sort for naming Jupiter's satellites (Io, Europa, Ganymede, and Callisto), despite the fact that he tried to pass off Galileo's discovery of them as his own.

1613 Mark Ridley (1560–1624), English physician, publishes *Short Treatise of Magneticall Bodies and Motions*, in which he discusses perpetual motion using magnets.

1613 J. Tissot of France unearths what he believes are the remains of the giant Teutobochus, the legendary king of the Cimbrians. Found in the Dauphine (southeast France) near the Castle of Langon, the remains are actually those of of a Deinotherium, a proboscidian (like an elephant) that became extinct during the Pleistocene era.

1613 Galileo Galilei (1564–1642), documents existence and movements of sunspots.

1614 Simon Marius (1570–1624), German astronomer also called Mayr, publishes his

Mundus Jovialis, which contains tables of mean periodic motions of the four known satellites of Jupiter. These tables precede those of Galileo and are more accurate.

1615 Santorio Santorio (1561–1636), Italian physician, publishes his *De Medicina Statica*, in which he describes his physiological investigations on human metabolism. He is the first to subject the human body to quantitative measurement.

1616 Fabio Colonna (1567–1650) of Italy writes his *Osservazioni sugli Animali Acquatici e Terrestri*, in which he states that the so-called "tongue stones" or "snakes's tongues" (glossopetrae) are, in fact, shark's teeth.

1616 First known cultivation of tobacco occurs in Virginia. It is believed that John Rolfe of Jamestown planted seeds a few years earlier that he may have obtained from the West Indies.

1616 Pope Paul V (1522–1621) forbids the teaching of the astronomical ideas of the Polish astronomer Nicolaus Copernicus (1473–1543) and places his *De Revolutionibus* on the index of forbidden books.

1617 The Guild of Apothecaries is founded in London.

1617 Willebrord van Roijen Snell (1591–1626), Dutch mathematician, publishes *Eratosthenes Batavius*, in which he develops the first method of determining distances by trigonometric triangulation. This founds the modern art of mapmaking.

1618 The first national pharmacopeia, *Pharmacopeia Londinesis*, is published in England.

1619 Christoph Scheiner (1575–1650), German astronomer, publishes his *Oculus*, in which he gives an experimental demonstration of the role of the retina, describes the eye's adjustment reflexes, and correctly explains the function of the crystalline lens.

1619 Daniel Sennert (1572–1637), German physician, publishes his *De Chymicorum*, which is the first application of Greek atomic theory to chemistry. Sennert speaks of atoms and even "second-level atoms" or molecules.

1619 Jean-Baptiste Morin (1583–1656), French physician, publishes his *Nova Mundi Sublunaris Anatomia* in which he makes the first reference to high temperatures within Earth.

1619 Johann Baptist Cysat (c.1586–1657), German astronomer and mathematician, publishes his *Mathemata Astronomica de Loco, Motu, Magnitudine, et Causis Cometae*. This contains the first telescopic observations of a comet, which he conducted over a period of two months. He also discovers the Orion nebula.

1619 Johannes Kepler (1571–1630), German astronomer, publishes his *Harmonices Mundi*, a mystical work of astronomical speculation in which he also says that there is an ongoing process in which earth decomposes matter to form other materials. He also states his third law of planetary motion. This shows the sun as the controller of planetary movement by stating that the square of the period of revolution of a planet is proportional to the cube of its distance to the sun.

1620 Francis Bacon (1561–1626), English philosopher, publishes his *Novum Organum*, in which he rejects the prevailing belief that the heavenly bodies travel in perfect circles. He unfortunately still cannot accept the idea that Earth is not the center of the universe.

1620 Gaspar Bauhin, in his *Prodomus Theatri Botanici*, offers descriptions of approximately 6,000 plants.

1620 Joachim Jung publishes works that make precise definitions of plant anatomy.

1621 Jan Baptista van Helmont (c.1577–1644), Flemish physician and alchemist, publishes his *De Magnetica*, which contains his elaborately detailed and often mystical theories on magnetism.

1621 Willebrord van Roijen Snell (1580–1626), Dutch mathematician, discovers that when a ray of light passes obliquely from a rarer into a denser medium (such as from air into water), it is bent toward the vertical. He then arrives at a general mathematical relationship to express this refraction of light by relating the degree of the bending of light to the properties of the refractive

material. This is a key discovery in optics, but it goes unpublished.

1621 Hieronymous Fabricius (also known as Girolamo Fabrizzi or Fabrizo d'Aquapendente; 1537–1619), Italian anatomist, uses the term "ovarium" in this posthumously published work.

1621 Johannes Kepler (1571–1630), German astronomer, publishes his *Epitome Astronomiae Copernicanae*, which is the most thorough and systematic treatment of the entire field of astronomy to date. In this work he also hypothesizes about an invisible force (gravity) that works in space, which he believes is a vacuum.

1621 Jan Baptista van Helmont (c.1577–1644), Dutch physician and alchemist, writes his *Ortus Medicinae*, in which he becomes one of the founders of modern pathology. He studies the anatomical changes that occur in disease. The book is not published until after his death.

1621 Pierre Gassendi (1592–1655), French philosopher, describes the aurora borealis and gives it its name.

1621 Galileo Galilei (1564–1642), Italian astronomer and physicist, publishes observations that the acceleration of a falling body is proportional to time elapsed and independent of density and weight.

1622 Edmund Gunter (1581–1626) of England notes that the declination of a magnetic needle varies at one spot both over time and space.

1623 Galileo Galilei (1564–1642), Italian astronomer and physicist, publishes his *Il Saggiatore*, in which he discusses a great deal of physics and champions the need for experimentation and mathematics.

1623 Gaspard Bauhin (1560–1624), Swiss physician, and his brother, Jean (1541–1613), devise a binominal nomenclature system in their book, *Pinax Theatri Botanici*, but have no idea of early groups.

1624 Adriaan van den Spigelius (1578–1625), Dutch anatomist, publishes the first account of malaria.

1625 Francesco Stelluti (1577–1640) of Italy makes the first microscopical observations to be published. He publishes his realistic drawing of a honey bee in a book of poems.

1625 Ipecac is first mentioned as "igpecaya" by a Portuguese priest in Purchas' book *Pilgrimes*. The dried rhizome and root of this tropical, South American creeping plant are valued as an emetic (induces vomiting).

1625 Nathanael Carpenter (1589–1635), English mathematician, publishes his *Geography*, in which he says mountains are continually being built up even as the weather wears others down.

1625 Santorio Santorio (1561–1636), Italian physician, describes his thermometer. This is the first clinical thermometer, as he obtains body temperature by placing it in the mouth.

1626 Gottfried Wendelin (1580–1667), Flemish astronomer, attempts to determine the distance of the sun using geometrical methods. Although his estimate is still one-third short of the actual distance, his conclusion that it is 60 million miles away is a vast improvement over ancient estimates and much more in keeping with the actual size of the solar system.

1627 Francis Bacon (1561–1626), English philosopher, considers oceanographic issues such as tides, waves, currents, depth, and salinity in his posthumously-published *Sylva Sylvarum*.

1627 A discussion by Gaspare Aselli (c.1581–c.1626), Italian physician, about the discovery of the lymph vessels (lacteals) that take up the end products of fat digestion from the intestine is published posthumously.

1627 Johannes Kepler (1571–1630), German astronomer, publishes the *Tabulae Rudolphinae*, which are tables for calculating the positions of the planets, the sun, and the moon. He uses Tycho Brahe's excellent observations as well as his own discoveries, resulting in the most accurate tables to date. He names them after his old protector, Emperor Rudolf II (1552–1612).

1628 First definite description of blood transfusion is published by Giovanni Colle (1558–1630), Italian physician, in his

Methodus Facile Procurandi Tuta et Nova Medicamenta.

1628 William Harvey (1578–1657), English physician, publishes his *De Motu Cordis et Circulatione Sanguinis*, in which he announces his discovery of the circulation of the blood. This scientific classic traces the course of blood through the heart, arteries, and veins and first demonstrates the correct theory of its circulation. His arguments are based on direct observation and brilliant, understandable experiments. It becomes a classic of science, and Harvey is considered the founder of modern physiology.

1629 Niccolo Cabeo (1585–1650) of Italy publishes his *Philosophia Magnetica*, in which he continues William Gilbert's experimental work on magnetism. He is the first to describe electrical repulsion.

1629 As the London Bills of Mortality begin to specify the cause of death, consumption or tuberculosis appears as a leading cause.

1629 Botanic Garden at Jena, Germany, is established.

1630 Christoph Scheiner (1575–1650), German astronomer, publishes his *Rosa Ursina*, which contains a detailed study on sunspots and offers several improvements on the telescope.

1630 Jean Rey (1582–1645), French physician, writes on the nature of air and its role in combustion and lays the foundation for future chemical discoveries. He suggests a possible experiment for weighing air that Galileo Galilei actually performs.

1630 Niccolo Zucchi (1586–1670), Italian mathematician and astronomer, builds his own telescopes and observes Jupiter.

c.1630 William Gascoigne (1612–1644), English astronomer, adapts the telescope for use as a measuring instrument in positional astronomy by devising cross hairs in the focal plane. With this invention, objects can be accurately centered at the intersection, and a micrometer can be used to measure angular separations. Gascoigne dies in battle during the English Civil War, but his work begins the transformation of the telescope into a real instrument of precision.

1631 Pierre Vernier (1584–1638), French military engineer, invents the vernier, a two-part scale that measures angles and lengths in small divisions. Consisting of a large stationary scale used to measure in whole numbers and an attached, small movable scale used to measure in fractions, its original applications are in astronomy. It eventually replaces the astrolabe, which was much more complicated to use. It finds its optimum use, however, in surveying.

1631 Pierre Gassendi (1592–1655), French philosopher, observes that the transit of Venus across the sun establishes its orbit lies closer to the sun than does Earth's orbit.

1631 Pierre Gassendi (1592–1655), French philosopher, observes a transit of Mercury across the disc of the sun. It occurs within five hours of when Johannes Kepler (1571–1630) had predicted, and it is the first planetary transit ever observed.

1632 In 1632, Galileo Galilei (1564–1642), Italian astronomer and physicist, publishes a work in Italian for the non-specialist, the *Dialogo Sopra I Due Massimi Sistemi del Mondo*, which openly and defiantly compares the Ptolemaic system unfavorably to the Copernican. For this, he is tried by the Inquisition in 1633 on charges of heresy and forced to recant the assertion that Earth moves about the sun.

1632 Pierre Gassendi (1592–1655), French philosopher, discovers that a part of the iron cross of the church of St. Jean at Aix in France possesses all the properties of a lodestone after being struck by lightning.

1632 First official astronomical observatory (one associated with a national body) is founded at Leiden University in Holland.

1632 Marco Aurelio Severino (1580–1656), Italian surgeon also known as Severinus, publishes his *De Recondita Abscessuum Natura*, which is the first modern manual of surgical pathology.

1632 Henry Gellibrand (1597–1636), English astronomer and mathematician, publishes

his findings that offer the first indication that Earth's magnetic field slowly changes over time.

1633 Stephen Bradwell publishes his *Helps in Suddain Accidents*, which is the first book on giving first aid to the injured.

1633 Galileo Galilei (1564–1642), Italian astronomer and physicist, is forced by the Roman Inquisition to renounce his earlier work in which he supported the sun-centered arguments of Copernicus. The 70-year-old Galileo admits the falseness of his writings and is sentenced to house arrest for the remainder of his life. History vindicates him as correct, however, despite his capitulation.

1634 Johannes Kepler (1571–1630), German astronomer, publishes his *Somnium*. This work of fiction is about a man who travels to the moon in a dream, and it is considered to be the first piece of authentic science fiction. In it, Kepler describes the lunar surface as it really is. This work also inspires others to consider the same theme.

1634 Thomas Moufet (1553–1604) of England publishes his *Theatre of Insects*. Both its text and illustrations are the best to date, and this work sets a new standard of exactness in the study of invertebrate animals.

1634 Willem Janszoon Blaeu (1571–1638), Dutch astronomer and geographer, publishes his *Institutio Astronomica Bipartita*, one part of which is based on the Ptolemaic system and the other on the Copernican scheme.

1635 Henry Gellibrand (1597–1636), English astronomer and mathematician, publishes *A Discourse Mathematicall on the Varaition of the Magnetic Needle*, detailing his findings that offer the first indication that Earth's magnetic field slowly changes over time. His readings made in London over many years demonstrate this, and to date, there is no satisfactory explanation for this occurrence. He also describes magnetic dip.

1635 Jean-Baptiste Morin (1583–1656), French physician and astronomer, offers an original method of determining longitude using the movements of the moon relative to the stars as a universal clock.

1636 Marin Mersenne (1588–1648), French mathematician and clergyman, publishes his *Harmonie Universelle*, in which he studies the physical basis of music. He reports several experiments on instruments that allow him to offer empirically derived rules.

1637 Pierre de Fermat (1601–1665), French mathematician, produces a mathematical derivation of the law of refraction. It contains the postulate that "nature operates by the simplest and most expeditious ways and means," which comes to be known as Fermat's principle.

1637 René Descartes (1596–1650), French philosopher and mathematician, publishes his *Dioptriques* as part of his larger work, *Discours de la Methode.*

1637 King Christian IV of Denmark (1577–1648) establishes a permanent astronomical observatory in Copenhagen.

1637 Padre Acugna, Spanish monk, introduces oil of copaiva to Europe. This tree, native to Brazil, contains a clear, transparent liquid the consistency of olive oil that is used as a stimulant, purgative, and diuretic.

1637 René Descartes (1596–1650), French philosopher and mathematician, publishes his *Discours de la Méthode*, in which he states that all science should be based on mathematics. While his contribution to experimental science is slight, his thinking exerts an enormous influence on physics.

1637 René Descartes (1596–1650), French philosopher and mathematician, writes the "Les Météores," an appendix to his book *Discours de la Méthode.*

1637 René Descartes (1596–1650), French philosopher and mathematician, offers physical explanations of refraction, rainbows, and clouds.

1638 Galileo Galilei (1564–1642), Italian astronomer and physicist, publishes his *Discorsi e Dimostrazioni Mathematiche Intorno a Due Nuove Scienze*, which lays the foundations of modern mechanics. In it he formulates what comes to be known

as the first law of motion (or the law of inertia), as well as the laws of cohesion and strength of materials and of the pendulum. It also provides a definition of momentum and details the steps or stages of what comes to be known as the experimental method. This work eventually spells the death of Aristotelian physics.

1638 Giovanni Battista Baliani (1582–1666) of Italy publishes his *De Motu Gravium Solidum*, in which he studies the phenomenon of impact.

1638 The first authenticated cure of fever by the use of chincona bark is made in Peru.

1638 Francis Godwin, English bishop, writes a fictionalized account of a manned flight to the moon titled *The Man in the Moone.*

1638 Johann Phocylides Holwarda (1618–1651), Dutch astronomer, identifies the first variable star, Omicron Ceti. This is the same star that Hieronymous Fabricius saw in August and that had disappeared by October.

1638 John Wilkins (1614–1672), English bishop, publishes *The Discovery of a World in the Moone*, which is a serious philosophical attempt to prove that the moon is populated by rational beings.

1639 Johannes Marcus Marci von Kronland (1595–1667), Bohemian physician, publishes his *De Proportione Motus*, which is the first work on impact (the action of two bodies in collision).

1639 First hospital in Canada is the Hôtel-Dieu. It is established in Quebec by the Duchesse d'Aguilon.

1639 Jeremiah Horrocks (1619–1641), English astronomer, is the first to observe the transit of Venus (which he also predicted after correcting Johannes Kepler's Rudolphine Tables). He then suggests that observations of such a transit from different places might create a parallax effect that could then be used to calculate the distance of Venus as well as the scale of the solar system. He is eventually proved correct.

1640 Evangelista Torricelli (1608–1647), Italian physicist, writes his *De Motu Gravium*, in which he applies Galileo Galilei's laws of motion to fluids and founds the study of hydrodynamics.

1640 John Wilkins (1614–1672), English bishop, publishes his *Discourse Concerning a New Planet*, in which he states the idea that nature is economical, using the shortest and easiest means to achieve its ends. He also defends the new astronomy of Copernicus, while attempting to reconcile it with the Bible.

1640 Pierre Gassendi (1592–1655), French philosopher, conducts an experiment that disproves the traditional argument that if one jumped high enough, he would land some distance from his original spot. This old example was used to argue against the notion of a moving Earth. Gassendi drops a stone from the top of a ship's mast and shows that the ship does not move out from under it. He also is responsible for rationalizing physics by reintroducing science to the atomism of the Greek philosopher Democritus (c.470–c.380 BC).

1640 Alvaro Alonso Barba, Spanish metallurgist, publishes his *Arte de los Metales*, in which he claims that Earth's ore deposits are not static but continually grow.

1640 Juan del Vigo introduces cinchona into Spain. Native to the Andes, the bark of this tree is processed to obtain quinine, used in the treatment of malaria.

1640 Niccolo Zucchi (1586–1670), Italian mathematician and astronomer, builds his own telescopes and observes spots on Mars.

c.1640 Pierre Gassendi (1592–1655), French philosopher, writes a biography of the Greek philosopher Epicurus (341–270 BC), which helps revive the ancient idea of atomism.

1640 Jeremiah Horrocks (1619–1641), English astronomer, establishes that the moon travels in an elliptical orbit about Earth.

1641 Athanasius Kircher (1601–1680), German scholar, publishes his *Magnes sive de Arte Magnetica*, in which he offers an original definition of universal magnetism that differs from that of William Gilbert.

1641 Guerner Rolfinck (1599–1673), German physician and chemist, becomes the first professor of chemistry in Germany.

1641 In 1641, René Descartes (1596–1650) publishes his principal philosophical work, *Meditationes de prima philosophia.*

1642 Blaise Pascal (1623–1662), French mathematician and physicist, builds a calculating machine that can add and subtract by means of cogged wheels. Called "La Pascaline," it is conceptually more ambitious than German mathematician Wilhelm Schickard's (1592–1635) machine, but it does not work as well. Still, it becomes well-known and publicly demonstrates that an apparently intellectual activity like arithmetic can be performed by a machine.

1642 First treatise on the use of cinchona bark (quinine powder) for treating malaria is written by Spanish physician Pedro Barba (1608–1671).

1642 Johann Georg Wirsung, German anatomist, discovers the pancreatic duct while performing a dissection in Padua, Italy.

1642 The first Western account of the disease beriberi is made in *De Medicina Indorum*, written by the Dutch physician J. Brontius.

1642 Pierre Gassendi (1592–1655), French philosopher, in *De motu impresso a motore translato*, extends Galileo Galilei's definition of inertia to include motion in any direction.

1643 Evangelista Torricelli (1608–1647), Italian physicist, is the first to create a sustained vacuum as he invents the barometer. He fills a four-foot-long glass tube with mercury and inverts it onto a dish. He observes that not all the mercury flows out, and that over time the level remaining in the tube varies. He concludes correctly that these changes are caused by atmospheric pressure.

1643 Gilles Personne de Roberval (1602–1675), French mathematician, states that gravity is found in all matter throughout the universe, and that it is the resistance of the ether found in space that keeps things apart from each other.

1644 Evangelista Torricelli (1608–1647), Italian physicist, publishes his short treatise *De Motu Gravium Maturaliter Descendentium* in which he develops Galilean dynamics.

1644 Kenelm Digby (1603–1665), English natural philosopher, observes magnetic and electrical attractions as well as acoustic resonance.

1644 René Descartes (1596–1650), French philosopher and mathematician, publishes his *Principia Philosophiae*, which contains the principles of Cartesian physics (the nonexistence of the vacuum, the constancy of the quantity of motion, and the infinite speed of light). He also offers his ideas about the origin and state of the universe, theorizing that the solar system is a continuously running machine, with space being full of a kind of matter he calls "plenum," which swirls around in vortices. Planets move by actual mechanical contact with the plenum. He also states that the planets are formed from whirling, fiery star-matter that cools from the surface inward. Earth's ore deposits come from molten veins of minerals that cooled.

1644 Robert Hooke (1635–1703), English physicist, invents the anemometer for measuring wind speed. It is a swinging-plate version that is able to measure the deflection of a vertically hanging piece of wood.

1645 The "Invisible College" is founded at Gresham College in London, England, and becomes the precursor of the Royal Society. The informal group was named by Robert Boyle (1627–1691) who used the term to describe the regular gathering of learned men with links to the universities who sought to promote the advancement of knowledge.

1646 Giovanni Battista Ferrari (1584–1655) of Italy publishes his *Hesperides sive de Malorum Aureorum Cultura et Usu* in Rome. This illustrated book is the first work entirely devoted to citrus fruits.

1646 Johann Rudolf Glauber (1604–1670), German chemist, publishes the first of his five-volume *Furni Novi Philosophici* (1646–1649). This work gives his recipes for mineral acids and salts including "sal mirabile"—the sodium sulfate residue that is formed by the action of sulfuric acid on ordinary salt—which becomes known as "Glauber's salt."

c.1646 John Greaves (1602–1652), English mathematician, studies the flow of water through the Straits of Gibraltar and into the Mediterranean and concludes that since there is no apparent outflow, there must be tunnels under the Mediterranean that connect to other seas.

1647 Blaise Pascal (1623–1662), French mathematician and physicist, publishes his *Experiences Nouvelles Touchant Le Vide*, in which he discusses the problem of a vacuum in a purely experimental way.

1647 Henri Duroy (1598–1679), Dutch physician also called Deroy, publishes his *Fundamenta Physices*, which is the first book written explicitly to spread and defend the notions of Cartesian physics.

1647 Johannes Hevelius (1611–1687), German astronomer, publishes his atlas of the moon, called *Selenographia*. He calls the dark, flat areas of the moon "seas" or "maria" in Latin—a name retained even today. Although he uses a telescope to study the moon, he refuses to use it to measure the positions of stars; he is the last important astronomer to insist on naked-eye observations.

1648 Blaise Pascal (1623–1662), French mathematician and physicist, conducts his famous experiment up the Puy de Dome mountain and not only verifies Torricelli's experiments, but goes beyond them to demonstrate that air pressure decreases as altitude increases.

1648 Johannes Marcus Marci von Kronland (1595–1667), Bohemian physician, discovers the diffraction of light, but it does not become a recognized fact until Isaac Newton's time.

1648 Giovanni Alfonso Borelli (1608–1679), Italian mathematician and physiologist, publishes his *Delle Cagioni delle Febbri Maligne della Sicilia negli Anni 1647 e 1648*, which contains the first description of an iatromechanical system. Borelli explains every aspect of the body using mechanics.

1648 Jean Pecquet (1622–1674), French physician, discovers the thoracic duct and the receptaculum chyli when dissecting a dog. He announces this in his book *Experimenta Nova Anatomica*.

1648 Jan Baptista van Helmont (c.1577–1644), Flemish physician and alchemist, has his writings published posthumously (*Ortus Medicinae*). He is the first to use quantitative methods in connection with a biological problem and thus is called the "father of biochemistry." He also is the first to recognize that more than one air-like substance exists, and he names this vapor (or non-solid) "chaos," a word for which the phonetic sound in Flemish is "gas." He classifies several types of "gases." He also describes the first quantitative experiment in plant physiology, demonstrating that a plant's growth is directly proportional to the loss of substance by the soil and the air.

1648 René Descartes (1596–1650), French philosopher and mathematician, writes *De Homine*, the first European textbook on physiology. He considers the body to be a material machine and offers his mechanist theory of life.

1648 Willem Piso (1611–1678), Dutch physician and botanist also called Le Pois), points out the effectiveness of ipecac against dysentery in his book *De Medicina Brasiliensi*. He is among the first to become acquainted with tropical diseases, and he distinguishes between yaws and syphilis.

1649 Daniel Sennert (1572–1637), German physician and academic, argues for a corpuscular theory of matter, and describes the process of fermentation as a process of the chemical changes in atoms and molecules.

1649 René Descartes, in *Traité des passions de l'âme*, holds that emotions are basically physiological.

1650 Athanasius Kircher (1601–1680), German scholar, conducts experiments with the newly-produced vacuum pump and demonstrates that sound cannot be conducted in the absence of air.

1650 Otto von Guericke (1602–1686), German physicist, constructs the first air pump, with which he is able to create a vacuum. He conducts several experiments using evacuated spheres that show a vacuum's proper-

ties. Animals cannot live in a vacuum nor will a candle burn.

1650 Bernhardus Varenius (1622–1650), German-Dutch geographer, publishes his *Geographia Generalis*, in which he says that earthquakes occur when nitre (potassium nitrate, KNO_3, also known as saltpeter) ignites, and the pressure from the sulfur vapors cannot escape through cracks in Earth. He views geography as encompassing all aspects of the surface of Earth, including living forms. This work becomes a standard geography text for over a century.

1650 Giovanni Battista Riccioli (1598–1671), Italian astronomer, discovers with a telescope that the middle star of the Big Dipper (called Mizar) is really two stars very close together. This is the first observation of a double star.

1650 Thomas Sydenham advances the hypothesis that diseases are caused by organisms residing in a host. Sydenham also documents the use of equinine and laudanum.

1651 Giovanni Battista Riccioli (1598–1671), Italian astronomer, publishes his *Almagestum Novum*, in which he introduces the practice of naming lunar features after great scientists and prominent historical figures. His moon maps have craters named after many of the great astronomers of the past, and these names are still used today.

1651 Johann Rudolf Glauber (1604–1670), German chemist, publishes his *Opera Mineralis*, in which he says that Earth's mineral deposits grow upward toward its surface from its center like the branches of a tree. He also offers the best description of the fusion process and of the composition of the metal used in mirrors (an alloy of copper, tin, and arsenic).

1651 Nathaniel Highmore (1613–1685), English surgeon, discovers the antrum or maxillary sinus when he pulls a patient's tooth.

1651 Nathaniel Highmore (1613–1685), English surgeon, publishes his *Corporis Humani Disquisitio Anatomica*, the first anatomical textbook to accept Harvey's theory of the circulation of the blood.

1651 William Harvey (1578–1657) publishes a landmark treatise on embryology entitled *On the Generation of Animals,* stating that all living things come from eggs. Harvey demonstrates that oviparous and viviparous generations are analogous to each other. Although Harvey discovered many errors in Aristotle's ideas, he supported the Aristotelian doctrine that generation occurs by epigenesis.

1651 In 1651, Thomas Hobbes (1588–1679), in *Leviathan*, argues from a mechanistic theory that man is a selfishly individualistic animal at constant war with others. In the state of nature, life is "nasty, brutish, and short."

1652 The first coffeehouse in London is established, centuries after the trade flourished in Italy.

1652 Thomas Bartholin (1616–1680), Danish anatomist, announces his discovery of the thoracic duct in humans in his *De Lacteis Thoracis*, published in Copenhagen. Bartholin articulated differences between the lymphatic and circulatory systems.

1653 Blaise Pascal (1623–1662), French mathematician and physicist, studies fluids and formulates what comes to be known as Pascal's principle—that the pressure at any point in a liquid is the same in all directions. Pascal's principle forms the basis of the hydraulic press, which he also describes in theory. This information is not published until a year after his death.

1653 Johann Joachim Becher (1635–1682), German chemist, writes that metals are deposited by vapors formed by sea water that penetrates underground and contacts a central fire.

1653 Olof Rudbeck (1630–1702), Swedish naturalist, discovers the lymphatics of the intestines. They are vessels or a vascular system of a type that were previously unknown.

1654 Francis Glisson (1597–1677), English anatomist and physiologist, keeps excellent clinical records and is able to give an accurate description of rickets, which becomes the classic account of this disease in children. He also breaks new ground with his study of the liver.

1654 In 1654, William Petty (1623–1687), working on Irish estates confiscates by Oliver Cromwell (1589–1658), carries out the first large scale attempt at a scientific survey.

1654 James Ussher (1581–1656), Protestant archbishop of Armagh, argues that a close reading of scriptural genealogies establishes that Earth was created around 4004 BC. Ussher's use of scriptural evidence was in opposition to abundant scientific and geological evidence that Earth was vastly older.

1656 Christiaan Huygens (1629–1695), Dutch physicist and astronomer, publishes his *De Motu Corporum ex Percussione*, in which he discusses the phenomenon of impact between elastic bodies.

1656 Christiaan Huygens (1629–1695), Dutch physicist and astronomer, discovers the first satellite of Saturn, which he names Titan because of its size. He also discovers that Saturn is surrounded by a thin ring and further announces his discovery of a huge cloud of gas and dust, the Orion Nebula.

1656 Christopher Wren (1632–1723), English architect and scientist, first injects opium into the veins of a dog.

1656 Guerner Rolfinck (1599–1673), German physician and chemist, demonstrates that a cataract is a clouding of the lens. When Rolfinck begins to conduct two annual dissections upon executed criminals at Jena in 1629, the practice is viewed with horror and amusement by the peasantry who warn of being "Rolfincked."

1656 Thomas Wharton (1614–1673), English physician, publishes his *Adenographia*, which is the first thorough treatment of all the then-known glands of the human body.

1656 Thomas Wharton (1610–1673) of England first uses the term "thyroid" in his *Adenographia*.

1656 Jacob Lumbrozo (1636–1665), Portuguese physician, arrives in Maryland and becomes the first Jewish physician to practice in America.

1657 Accademia del Cimento is founded in Florence, Italy. Supported by the Medici family and the Grand Duke of Tuscany nearly a decade before its formal creation, this early scientific society is organized by two of Galileo's pupils, the Italian mathematician Vincenzo Viviani (1622–1703) and the Italian physicist Evangelista Torricelli (1608–1647). They enroll some of the leading men of science to come together for laboratory experimentation and discussion. They eventually publish an account of their work.

1657 Gaspar Schott (1608–1666) of Germany publishes his *Mechanica Hydraulica-Pneumatica*, in which he reports on the experiments of the German physicist Otto von Guericke (1602–1686).

1657 Otto von Guericke (1602–1686), German physicist, conducts one of the more spectacular experiments in the history of physics. He demonstrates the power of a vacuum to Emperor Ferdinand III (1608–1657) by showing that not even two teams of eight straining horses can pull apart two attached copper spheres from which all the air has been evacuated. He puts an end to the ancient notion that "nature abhors a vacuum."

1657 Robert Boyle (1627–1691), British physicist and chemist, uses an improved air pump made by English physicist Robert Hooke (1635–1703) and proves that Galileo was correct in stating that all objects fall at the same velocity in a vacuum. He also demonstrates that a clock ticks silently in a vacuum.

1657 First reference to a bronchocele (goiter) in English is made by Tomlinson.

1657 Mikkel Pederson Escholt (c.1610–1669), Norwegian geologist, publishes his *Geologica Norvegica*, which is the first scientific treatise printed in Norway. It is the first to use the word "geology" in the modern sense—as the science of Earth—and offers a clear and near-modern view of earthquakes.

1658 Franciscus Sylvius de la Boë (1614-1672), German-Dutch chemist and physiologist, builds the first university chemistry laboratory in Leyden, Holland, where he teaches

from 1658–1672. He is also one of the first to appreciate the idea of chemical affinity (attractions).

1658 Johann Jakob Wepfer (1620–1695), German physician, declares that burst blood vessels in the brain cause apoplexy or strokes.

1658 Dutch naturalist Jan Swammerdam (1637–1680) publishes records of observations of red blood cells.

1659 Christiaan Huygens (1629–1695), Dutch physicist and astronomer, publishes his *De Vi Centrifuga*, in which he discusses the phenomenon of centrifugal force. He also discovers that a centripetal force is required to maintain a body in circular motion and offers a mathematical expression to govern such a force.

1659 Christiaan Huygens (1629–1695), Dutch physicist and astronomer, is the first to note and record the surface markings on the planet Mars.

1659 Walter Charleton (1619–1707) of England publishes the first physiology textbook in English, *Natural History of Nutrition, Life, and Voluntary Motion.*

1660 Otto von Guericke (1602–1686), German physicist, invents a frictional electrical device, which is the first machine to generate an electrical charge. His hand-rotated globe of sulfur accumulates static electricity, and he is able to conduct several electrical experiments with it, most notably establishing the principle of electrical repulsion.

1660 Robert Boyle (1627–1691), British physicist and chemist, publishes his *New Experiments Physico-Mechanicall Touching the Spring of Air and Its Effects*, in which he documents his experiments with an improved pump (to produce a vacuum).

1660 Robert Boyle (1627–1691), English physicist and chemist, publishes his *New Experiments Physico-Mechanicall*, in which he suggests that combustion and respiration are similar processes.

1660 Vincenzo Viviani (1622–1703), Italian mathematician, and Giovanni Alfonso Borelli (1608–1679), Italian mathematician and physiologist, collaborate on an experiment in which they measure the velocity of sound by using the cannon-flash-and-sound method.

1660 Conrad Viktor Schneider (1614–1680) of Germany offers a new concept of the mucous membranes of the nose in his *De Catarrhis.* He shows that there is no direct connection between the nasal cavities and the brain.

1660 Gabriel Mouton (1618–1694), French mathematician and astronomer, devises a practical computational method using a pendulum to measure with high accuracy the apparent diameter of the sun at its apogee.

1660 The Royal Society of London is founded in England with Henry Oldenburg (c.1618–1677) as its Secretary and Robert Hooke (1635–1702) as the Curator of Experiments. Two years later (1662), King Charles II (1630–1685) grants it a royal charter, and it becomes known as the "Royal Society of London for the Promotion of Natural Knowledge."

1661 Johannes Hevelius (1611–1687), German astronomer, records his observation of a transit of Mercury across the disc of the sun.

1661 John Evelyn (1620–1706) of England publishes his attack on air pollution, *The Smoke of London.*

1661 Marcello Malpighi (1628–1694), Italian physiologist, publishes his *De Pulmonibus Observationes Anatomicae*, in which he relates his discovery of anastomosis (the body's network of capillaries, including individual capillaries and vascular capillary beds, in the tissues of the lungs) and describes his observation of the passage of blood through the capillaries. Also, using the newly-invented microscope, he observes the stomates in leaves and studies the structure and life of the silkworm.

1661 Nicolas Steno (1638–1686), Danish anatomist and geologist, first describes the parotid duct (the salivary gland near the angle of the jaw). It becomes known as the duct of Steno.

1661 Robert Boyle (1627–1691), English physicist and chemist, publishes his book *The*

Sceptical Chymist. Many consider this work as marking the beginning of scientific chemistry. In it, Boyle espouses the experimental method and breaks from the Greek notion of elements.

1662 Robert Boyle (1627–1691), British physicist and chemist, discovers the law that when an ideal gas is under constant temperature, its volume and pressure vary inversely. This inverse relationship becomes known as Boyle's law.

c.1662 Robert Hooke (1635–1703), English physicist, tests the hypothesis that gravity might be a force that varies with distance. He weighs the same object at Earth's surface, deep below it in mines, and from high elevations, but he arrives at inconclusive results.

1662 Coffee is first introduced into France.

1662 Geminiano Montanari (1633–1687), Italian mathematician and astronomer, completes his detailed map of the moon.

1662 Johannes Hevelius (1611–1687), German astronomer, edits and publishes *Venus in Sole Visa.* This is a posthumous account of the first observation of the transit of Venus in 1639 by the English astronomer, Jeremiah Horrocks (1619–1641).

1662 John Graunt (1620–1674), English statistician, founds vital statistics (as opposed to medical statistics) with the London publication of his book *Natural and Political Observations upon the Bills of Mortality.* His application of mathematics to the study of human populations makes him the founder of the science of demography.

1662 Lorenzo Bellini (1643–1704), Italian anatomist, publishes his study of the structure of the kidney, *Exercitatio Anatomica de Structura et Usu Renum*, at the age of nineteen. He discovers the tubules or excretory ducts of the kidneys.

1663 First hospital in North America is established in New York.

1663 Isaac Vossius (1618–1689), Dutch scholar, publishes *De Motu Marium et Ventorum*, in which he states correctly that the overall ocean circulation of the North Atlantic region is essentially clockwise.

1663 One year after the death of the French mathematician, physicist, and philosopher Blaise Pascal (1623–1662), his *Traité de la grande expérience de L'équilibre des liqyuers et de la pesanteur de la masse de l'air* is published. It has much to do with the founding of the study of liquid mechanics.

1663 Nicholas Steno (1638–1686) asserts that the heart is a muscle or muscular organ.

1663 James Gregory (1638–1675), in his *Optica Promota*, sets forth the physics of a reflecting telescope.

1664 Jan Swammerdam (1637–1680), Dutch naturalist and microscopist, discovers the valves of the lymphatics.

1664 René Descartes (1596–1650), French philosopher and mathematician, first puts forth the idea of reflex action. It is included in a French version of his work on animal physiology published several years after his death. He applies his mechanistic philosophy to the analysis of animal behavior and first uses the concept of reflex to mean any involuntary response the body makes when exposed to a stimulus.

1664 Robert Hooke (1635–1703), English physicist, reports on his observations of a large oval shape on the planet Jupiter. This is later known as the Great Red Spot, which is actually an anticyclonic storm that has been in existence since at least its first observation.

1664 Thomas Willis (1621–1675), English physician, writes his *Cerebri Anatome*, which gives a complete and accurate account of the nervous system. He also first describes the spinal accessory nerve and gives an improved account of cranial nerves. After tracing the blood flow to the brain, he suggests that the cerebellum governs involuntary movement and that thinking takes place in the large cerebrum. His influential book is illustrated by the famous English architect and scientist Christopher Wren (1632–1723).

1665 Francesco Maria Grimaldi (1618–1663), Italian physicist, has his discovery of the diffraction of light published posthumously under the title *Physico-Mathesis de Lumine, Coloribus, et Iride.* This work describes an experiment in which he lets a beam of light

pass through two narrow apertures, one behind the other, and then onto a blank surface. When he notes that the band of light on the surface is slightly wider than it should be, he concludes that the light beam has been bent slightly outwards. He names this phenomenon diffraction.

1665 *Philosophical Transactions* of the Royal Society of London is first published.

1665 Athanasius Kircher (1601–1680), German scholar, publishes his *Mundus Subterraneus*, in which he states that fossils were once living organisms. He also says that heat drives magma from Earth's core up through volcanoes, and that most mountain ranges run north-south because of tidal action. This work becomes a standard geological text for some time.

1665 A bubonic plague epidemic in London kills 75,000 people. It is during this scourge that English scientist and mathematician Isaac Newton (1642–1727) leaves school in London and stays at his mother's farm in the country. There he formulates his laws of motion.

1665 Denis de Sallo (1626–1669), French poet and publisher, publishes the first scientific journal, *Journal des Scavans*, in Paris.

1665 The first drawing of a cell is made by Robert Hooke (1635– 1703), English physicist. While observing a sliver of cork under a microscope, Hooke notices it is composed of a pattern of tiny rectangular holes he calls "cells," because each looks like a small, empty room. Although he does not observe living cells, the name is retained.

1665 Giovanni Alfonso Borelli (1608–1679), Italian mathematician and physiologist, publishes his *Del Movimento della Cometa*, in which he suggests that comets follow a parabolic path (curved like an open hairpin) and never return.

1665 Giovanni Domenico Cassini (1625–1712), Italian-French astronomer, successfully measures the rotational speed of the planet Jupiter.

1665 Richard Lower (1631–1691), English physician, transfuses blood from one dog to another.

1665 Robert Hooke (1635–1703), English physicist, argues that fossils are simply shells that filled with clay and then hardened, becoming in a sense impressions of things that once lived.

1665 Robert Hooke (1635–1703), English physicist, improves the design of the compound microscope and uses his own device to observe insects and plants. He publishes his landmark book on microscopy called *Micrographia* this year. This highly popular work is the first major collection of microscopical sketches. Containing some of the most beautiful drawings of microscopic observations ever made, his book led to many discoveries in related fields. He also compares light with waves in water. This is the first serious opposing theory to the Pythagorean concept of light as a stream of particles. In addition, he offers a thorough treatment of combustion and suggests that air is composed of two parts.

1666 Robert Boyle (1627–1691), English physicist and chemist, publishes his *Hydrostatical Paradoxes*, in which he details his experiments with fluids and refutes the old doctrine that a light liquid can exert no pressure against a heavier fluid.

1666 The members of the Accademia del Cimento of Florence, Italy, publish *Saggi di Naturali Esperienze*, which is an account of their joint experiments and discoveries. The most important sections of this work are those that deal with the measurement of temperature and of atmospheric pressure. The most detailed section is devoted to experiments on the natural pressure of the air. With its strict scientific methods and its overall focus on experimental physics, this work becomes the laboratory manual of the eighteenth century and is regarded by many as the beginning of modern physics.

1666 The Académie des Sciences is founded in Paris. This French academy holds its first official meeting in the library of King Louis XIV (1638–1715), indicating how different this royally-sponsored group is from its English counterpart. The Royal

Society of London is a private creation, and receives royal approval but nothing more. The twenty members of the French Académie are salaried by the king.

1666 Giovanni Alfonso Borelli (1608–1679), Italian mathematician and physiologist, publishes his *Theoricae Mediceorum Planetarum*, in which he considers why Jupiter has satellites. He suggests that it is the result of a balance between centripetal and centrifugal forces.

1666 Giovanni Domenico Cassini (1625–1712), Italian-French astronomer, makes the first observation of the polar caps on Mars.

1666 Heinrich Meibom (1638–1700), German physician and anatomist, announces his discovery of the conjunctival glands in his book *De Vasis Palpebrarum.*

1666 Isaac Newton (1642–1727), English physicist and mathematician, first conceives of the theory of universal gravitation. It is during this plague year, which he spends at his mother's farm (because the schools are closed), that he supposedly watches an apple fall to the ground and starts to wonder if the same force that pulls the apple downward also holds the moon in its grip. He later refines his early calculations.

1666 Jean Picard (1620–1682), French astronomer, perfects the telescope as an accurate instrument to measure angular widths and separations between objects in the sky. He improves Gascoigne's addition of the micrometer.

1666 Jean-Baptiste Denis (1643–1704), physician to French King Louis XIV (1638–1715), first transfuses blood from an animal (a lamb) to a human subject. The patient improves temporarily but then dies.

1666 Robert Boyle (1627–1691), English physicist and chemist, publishes *The Origine of Formes and Qualities*, in which he begins to explain all chemical reactions and physical properties through the existence of small, indivisible particles or atoms.

1667 Giovanni Alfonso Borelli (1608–1679), Italian mathematician and physiologist, publishes his *De Vi Percussionis*, which deals with the phenomenon of impact among other physical topics.

1667 Ismael Boulliau (1605–1694) of France attempts to explain the changes in a star's brightness by stating that stars rotate and have dark spots.

1667 John Ray (1627–1705), English botanist, founds systematic biology with the publication of his book about the flora of the British Isles. This work is a catalog of the flowers of Cambridgeshire, England, titled *Catalogous Plantarum circa Cantabrigium Nascentium*, and it is the first book of local flora to be published.

1667 Nicolas Steno (1638–1686), Danish anatomist and geologist, introduces the term "ovary" for the female reproductive gland, saying that the female testes contain ova.

1667 Walter Needham (c.1631–c.1691), English anatomist, demonstrates that the fetus is nourished by the placenta.

1668 François Mauriceau (1637–1709), French physician, publishes his important work on obstetrics. In *Traité des Maladies des Femmes Grosses*, he is the first to refer to tubal pregnancy and to correct the ancient view that the pelvic bones separate during labor.

1668 Francesco Redi (1626–1697), Italian physician, conducts experiments to disprove spontaneous generation and shows that maggots are not born spontaneously, but come from eggs laid by flies. He publishes his *Esperienze Intorno all Generazione degli Insetti.*

1668 Giovanni Domenico Cassini (1625–1712), Italian-French astronomer, publishes his *Ephemerides Bononiensis Mediccorum Siderum.* The tables of the motions of Jupiter's satellites from the book are used later to determine longitude. It is on the basis of these tables that Danish astronomer Ole Rømer (1644–1710) is able to demonstrate that light has a finite velocity.

1668 Jan Swammerdam (1637–1680), Dutch naturalist, discovers that the "bee-king" is really a queen.

1668 Johannes Hevelius (1611–1687), German astronomer, publishes his *Cometographia*,

in which he offers an extensive account of the comets of the previous two centuries.

1668 Marcello Malpighi (1628–1694), Italian physiologist, coins the term "corpus luteum" to describe certain endocrine tissue in the mammalian reproductive system.

1668 Regnier de Graaf (1641–1673), Dutch anatomist, writes his treatise on the human sex organs and confirms Harvey's analogy between oviparous and viviparous reproduction. He also describes changes in "hydatid vesicles" or Graafian follicles, which he takes to be eggs and says are associated with reproduction.

1668 Robert Hooke (1635–1703), English physicist, argues that earthquakes are caused by the cooling and contracting of Earth.

1668 The first successful intravenous injection on a human is made by the German physician Johann Daniel Major (1634–1693). At nearly the same time, another German doctor, Johann Sigmund Elsholtz (1623–1688), has the same success.

1669 Nicolas Steno (1638–1686), Danish anatomist and geologist, argues that Earth is layered with the fossil remains of once-living organisms, and that "tongue stones" are really shark's teeth. He also describes rock stratification and states what comes to be known as the first law of crystallography: The crystals of a specific substance have fixed characteristic angles at which the faces, however distorted they may be, always meet.

1669 Erasmus Bartholin (1625–1698), Danish physician, discovers the optical phenomenon he names double refraction. He notes that images seen through Icelandic feldspar (calcite) are not only doubled, but that when the crystal is rotated, one image remains still while the other whirls with the crystal. He calls the stationary light beam the "ordinary beam" and the moving image the "extraordinary beam." This is not explained until polarized light becomes better understood in the early nineteenth century.

1669 John Wallis (1616–1703), English mathematician, publishes his *Mechanica*, in which he refutes many of the errors regarding motion that had persisted since Greek times. He also gives a more rigorous meaning to such terms as force and momentum.

1669 The first tea is brought into England.

1669 Geminiano Montanari (1633–1687), Italian mathematician and astronomer, observes that the "Demon Star" (Algol or Beta Persei) is a variable star, changing from a second to a third magnitude brightness.

1669 Jan Swammerdam (1637–1680), Dutch naturalist, begins his pioneering work on the metamorphosis of insects and the anatomy of the mayfly.

1669 Jan Swammerdam (1637–1680), Dutch naturalist, makes the first published reference to the "preformation theory."

1669 Johann Joachim Becher (1635–1682), German chemist, publishes his *Physica Subterranea*, in which he is the first to attempt the formulation of a general theory of chemistry. His concept of "terra pinguis" as the substance in air that burns forms the basis of the later phlogiston theory.

1669 Mount Etna erupts and causes a major geological event. Located in northeast Sicily, Italy, near the coast, its lava flow passes the town of Catania and flows out to sea, joining the island of Castello Ursino to the mainland. The dramatic eruption is described in many reports and chronicles and stimulates further interest in geology.

1669 Richard Lower (1631–1691), English physician, publishes his *Tractatus de Corde*, in which he discovers the nature of respiration and also shows that the vagus nerve controls the heart.

1669 Richard Lower (1631–1691), English physician, shows that venous blood takes up air in the lungs. He concludes correctly that the dark venous blood is changed to bright red when it absorbs some of the air passing through the lungs.

1669 Nicolas Steno (1638–1686) argues for a sequence of distinct geological phases that explains land topography changes (e.g., mountain building) and postulates on the origins of existing landforms.

1670 Agostino Scilla (1629–1700), Italian geologist, publishes *La Vana Speculazione Disingannata dal Senso.* Its study of fossils and their relation to living organisms makes it a classic of geology.

1671 Jacques Rohault (1620–1675), French physicist, publishes his *Traite de Physique*, which is an extremely clear and extensive treatment of Cartesian physics. It is largely because of this work that René Descartes' ideas hold for so long in France (over those of Newton).

1671 Giovanni Domenico Cassini (1625–1712), Italian-French astronomer, calculates the distance from Earth to Mars and uses this data to estimate the distances of all the planets from the sun. His values are remarkably accurate. He also discovers the second satellite of Saturn, which he names Iapetus.

1671 Jean Picard (1620–1682), French astronomer, makes the first measurement of Earth that is more accurate than that of the Greek Eratosthenes. He uses the same principles as Eratosthenes, but substitutes the point of a star for the large body of the sun and therefore is more accurate. He gives Earth a circumference of 24,876 miles and a radius of 3,950 miles (values close to those accepted today).

1671 Michael Ettmüller (1644–1683), German physician, attributes the contagiousness of tuberculosis to the sputum.

1671 Robert Boyle (1627–1691), English physicist and chemist, produces hydrogen by dissolving iron in hydrochloric or sulfuric acid, but he does not realize his achievement.

1671 Theodore Kercking (1640–1693), German-Dutch anatomist, states that "female testicles" in mammals are the equivalent of ovaries in birds and also produce ova.

1672 Jean Richer (1630–1696), French astronomer, finds that the same pendulum clock loses two and one-half minutes in Cayenne, French Guiana, as opposed to its former location in Paris. This leads to his correct conclusion that the force of gravity differs in magnitude at different parts of the globe. This notion becomes important to geophysics. He also infers that the force of gravity is less at Earth's equator than at higher latitudes, and that Earth's diameter is greater at the equator than at the poles.

1672 Isaac Newton (1642–1727), English physicist and mathematician, publishes his letter on light in the Royal Society's *Philosophical Transactions.* This letter, which is his first scientific publication, details his prism experiments of 1666 and offers findings that reveal for the first time the true nature of light. He recounts how he let a ray of sunlight enter a darkened room through a small hole and then passed the ray through a prism onto a screen. The ray was refracted, and a band of consecutive colors in rainbow order appeared. He then passed each separate color through another prism and noted that although the light was refracted, the color did not change. From this, he deduces that sunlight (or white light) consists of a combination of these colors. Later he elaborates further on this ground-breaking experiment

1672 Otto von Guericke (1602–1686), German physicist, publishes his *Experimenta Nova (ut vocantur) Magdeburgica de Vacuo Spatio*, in which he describes his dramatic experiments with a vacuum performed before Emperor Ferdinand III.

1672 Francis Glisson (1597–1677), English physician, introduces the concept of irritability (inherent muscular force) as a property of living tissue in his *Tractatus.*

1672 Franciscus Sylvius (1614–1672), Dutch physician, publishes his *Idea Praxeos Medicae*, in which he asserts that all physiological phenomena can be explained by chemistry. He is the leading proponent of what is called the iatrochemical school.

1672 Ipecac is introduced into Europe in Paris this year. The root of the Brazilian plant ipecacuanha is used to cure dysentery.

1672 George Sinclair, Scottish mathematician, publishes *The Hydrostaticks*, in which he explains and illustrates the structure of coal beds.

1672 Giovanni Domenico Cassini (1625–1712), Italian-French astronomer, determines the parallax of Mars using his observations and those of the French astronomer Jean Richer (1630–1696), who made his from French Guiana. This gave Cassini a value for the distance of Mars and enabled him to calculate closely the distance of the sun from Earth. He also discovers four satellites of Saturn.

1672 Giovanni Domenico Cassini (1625–1712), Italian-French astronomer, discovers the third satellite of Saturn, which he names Rhea.

1672 Gottfried Wilhelm Leibniz (1646–1716), German mathematician and philosopher, begins to build a calculator capable of multiplication and division as well as addition and subtraction. Called the Stepped Reckoner, it is a complicated machine that has special gears called Leibniz wheels.

1672 John Josselyn (fl.1638–1675), English botanist, lists 23 plants that have been introduced to England from America. By 1713, there are at least 400 such new plants in England.

1672 Marcello Malpighi (1628–1694), Italian physiologist, publishes his *De Ovo Incubato* and traces the first hours in the development of a hen's egg with his microscope. He concludes for preformation.

1672 The Paris Observatory is completed. Built in Paris as an adjunct to the Académie Royale des Sciences, this astronomical observatory is paid for by the state and is both well-staffed and well-equipped. It is designed by the French physician and architect Claude Perrault (1613–1688).

1672 Regnier de Graaf (1641–1673), Dutch anatomist, publishes his *Tractatus Anatomico-Medicus de Succi Pancreatici Natura et Usu*, a pioneering study of pancreatic juice.

1672 Thomas Sherley (1638–1678) of England speculates that seeds rise from Earth's interior and, like plants, grow into metals and stones.

1672 Thomas Willis (1621–1675), English physician, describes creeping paralysis and dementia praecox.

1673 Christiaan Huygens (1629–1695), Dutch physicist and astronomer, publishes his *Horologium Oscillatorium*, in which he details his invention of the pendulum or "grandfather clock." He employs Galileo's principle of isochronicity and ingeniously adapts it to the inner workings of a clock, beginning the era of accurate timekeeping that is so important to the advancement of physics. This highly original work not only demonstrates great mechanical ability but superior mathematical theorizing as well.

1673 Antoni van Leeuwenhoek (1632–1723), Dutch biologist and microscopist, contacts the Royal Society of London and they begin publishing (in the form of letters) the important discoveries he makes using his simple but powerful microscope. He makes microscopic observations of the blood and gives a precise description of red corpuscles.

1673 Johannes Hevelius (1611–1687), German astronomer, publishes the first of his two-part *Machinae Coelestis*; the exquisitely detailed plates show astronomical instruments that he designed and made.

1673 John Ray (1628–1705), English naturalist, writes in his *Observations Topographical, Moral, and Physiological* that in order for mountains to have formed naturally, the world must be extremely old and must have changed considerably over time.

1674 Antoni van Leeuwenhoek (1632–1723), Dutch biologist and microscopist, observes "animacules" in lake water viewed through a ground glass lens. This observation of what will eventually be known as bacteria represents the start of the formal study of microbiology.

1674 French physician Morel de Villiers invents the tourniquet for stopping major hemorrhages.

1674 Hennig Brand (c.1630–c.1692), German chemist, discovers phosphorus, which he finds in urine. This is the first discovery of an element that was not known in any earlier form.

1674 John Mayow (1641–1679), English physiologist, publishes his *Tractatus Quinque*

Medico-Physici, in which he compares respiration (breathing) to combustion. He is the first to state that the volume of air is reduced in respiration. He is also ahead of his time when he correctly asserts that the blood carries air from the lungs to all parts of the body.

1674 Pierre Perrault (c.1611–1680), French hydrologist, publishes *De l'Origine des Fontaines* anonymously. He shows conclusively that precipitation is more than adequate to sustain the flow of rivers. His field work on the Seine River is instrumental in establishing the science of hydrology on a quantitative basis.

1674 Robert Hooke (1635–1703), English physicist, publishes "An Attempt to Prove the Motion of the Earth," in which he works out an imperfect theory of planetary gravitation that anticipates that of Isaac Newton.

1675 Jean Picard (1620–1682), French astronomer, is the first to observe an electric glow in the vacuum of a barometer.

1675 Giovanni Domenico Cassini (1625–1712), Italian-French astronomer, discovers that the ring around the planet Saturn is actually a double one. The two rings are divided by a dark gap that is still called Cassini's division or the Cassini gap.

1675 John Josselyn (fl.1638–1675), English botanist, publishes an account of the plants and animals he encounters while living in America and indicates that tuberculosis existed among the Native Americans before the coming of the Europeans.

1675 Nicolas Lémery (1645–1715), French chemist and physician, publishes his *Cours de Chymie*, which becomes the authoritative textbook on chemistry for the next fifty years. He is an adherent of Boyle's and advocates the experimental method.

1675 The Royal Greenwich Observatory is founded by Charles II of England (1630–1685) to improve knowledge of the positions of the celestial bodies as an aid to navigation. John Flamsteed (1646–1719) becomes the first Astronomer Royal when the building is completed the next year. It is through Greenwich that the prime meridian passes, from which longitude is measured east and west to all parts of Earth.

1675 Ole Rømer (1644–1710), Danish astronomer, first announces his calculation of the speed of light at the Academy of Sciences in Paris. By observing the motions of Jupiter's satellites at different times of the year, he comes to conclude that light must have a finite velocity. Until this, most agreed with René Descartes that light had an infinite speed. Rømer then studies the irregularities of Jupiter's satellite as seen from Earth and is able to calculate the speed of light at 227,000 kilometers a second. He was not far off from the correct value of 299,792 kilometers a second.

1676 Edme Mariotte (1620–1684), French physicist, independently discovers Boyle's law and adds an important qualification to it. Like Boyle, he notes that air expands with a rising temperature and contracts with a falling temperature, but he adds that the inverse relationship between temperature and pressure only holds if the temperature is kept constant. Because of this, Boyle's law is called Mariotte's law in France.

1676 Gottfried Wilhelm Leibniz (1646–1716), German philosopher and mathematician, criticizes René Descartes' ideas of motion and formulates his own theory of dynamics, which substitutes kinetic energy for the conservation of movement.

1676 Edmund Halley (1656–1742), English astronomer, establishes the first observatory in the southern hemisphere on the island of St. Helena in the South Atlantic.

1676 Isaac Newton (1642–1727), English physicist and mathematician, demonstrates before the Royal Society that an excited glass globe (one that is rubbed by his hands) will attract any light bodies, even to the surface opposite to that being rubbed.

1677 Antoni van Leeuwenhoek (1632–1723), Dutch biologist and microscopist, discovers spermatozoa and describes them in a letter he publishes in *Philosophical Transactions* in 1679. In the same year, Johan Ham also

sees them microscopically, but the semen he observes comes from a patient suffering from gonorrhea, and Ham concludes that spermatozoa are a consequence of the disease.

1678 Francesco Redi (1626–1697), Italian physician, is the first to communicate the fact that the electric shock of the torpedo fish may be transmitted to the fisherman through the line and rod.

1678 Robert Hooke (1635–1703), English physicist, publishes his *Lectures...Explaining the Power of Springing Bodies*, in which he states the law of elasticity, now known as Hooke's law. This law states that the force tending to restore a spring to the equilibrium position is proportional to the distance by which it is displaced from that equilibrium position.

1678 Edmund Halley (1656–1742), English astronomer, publishes the first catalog of telescopically-obtained coordinates of stars in the southern hemisphere.

1678 Martin Lister (1638–1712), English zoologist and an expert on living mollusks, publishes his *Historiae Animalium Angliae*, in which he says that fossils are unique types of rocks but are not forms of things that once lived.

1678 Edmond Halley argues that Earth's distance from the sun can be measured by solar parallax during transits of the sun by the "inner" planets Mercury and Venus.

1679 Denis Papin (1647–1712), French physicist, develops a steam digester that is the forerunner of the pressure cooker. Work on this device leads him to later experiment with steam pushing a piston.

1679 Augustus Quirinus Bachmann (1652–1723), German anatomist and botanist also called Rivinus, discovers the sublingual gland.

1679 The first medical periodical published in the vernacular is *Nouvelles Découvertes sur Toutes les Parties de la Médecine* by French physician Nicolas de Blegny (c.1646–1722) in Paris.

1679 Joachim Jung (1587–1657), German botanist, has his *Isagoge Phytoscopia* published posthumously, and it contains ideas of a binomial system that greatly influences Carl Linnaeus (also known as Carolus Linnaeus).

1680 Edme Marriote (1620–1684), French physicist, advances the mechanics of materials by his discovery of the elongation and compression of beam fibers.

1680 Antoni van Leeuwenhoek (1632–1723), Dutch biologist and microscopist, discovers yeast cells.

1680 Giovanni Alfonso Borelli (1608–1679), Italian mathematician and physician, has his *De Motu Animalium* published posthumously. He considers the body a machine whose make-up and operations are entirely understandable by mechanical laws. He applies René Descartes' mechanistic philosophy to the working of the human body and declares physiology to be a branch of physics.

1680 Gottfried Wilhelm Leibniz (1646–1716), German philosopher and mathematician, writes in his *Protogaea* that fossils, but not crystals, are organic in origin. He also states that Earth's history can be seen in the organic remains found in the successive layers of strata.

1680 Isaac Newton (1642–1727), English physicist and mathematician, is the first to attempt to measure the quantity of heat received by Earth from the sun. He estimates that it is "about 2,000 times that of red-hot iron."

1680 The dodo bird becomes extinct because of excessive hunting by sailors in the Indian Ocean.

1680 Thomas Sydenham (1624–1689), English physician, prescribes quinine as a specific drug for malaria.

1681 First use of the term "comparative anatomy" is made by Nehemiah Grew (1641–1712), English botanist and physician.

1681 Georg Samuel Dirffel (1643–1688), German astronomer, publishes a work in which he represents the orbit of a comet as a parabola with the sun at the focus.

1681 Gerard Blasius (c.1626–c.1692), Dutch anatomist, publishes his *Anatome Animalium Terrestrium Variorum*, which is the first general systematic treatise on comparative anatomy.

1681 Johann Joachim Becher (1635–1682), German chemist, obtains tar from the distillation of coal. He also suggests that sugar is necessary for fermentation.

1681 Thomas Burnet (1635–1715), English cleric, publishes his *Sacred Theory of the Earth*, in which he explains the scriptural creation and flood by natural processes. The perfect world of the creation became a rough, ruined place after the flood, he says. Despite his religious framework, his emphasis on the shaping power of natural forces is an important contribution to the future science of geology.

1682 John Ray (1628–1705), English naturalist, publishes his book *Methodus Plantarum Nova*, which divides flowering plants into monocotyledons and dicotyledons.

1682 Peruvian bark (cinchona), which contains quinine, is mentioned in a poem by French poet Jean de La Fontaine (1621–1695).

1683 Edmund Halley (1656–1742), English astronomer, states that Earth's magnetism is caused by four poles of attraction, two of them being in each hemisphere near each pole of Earth.

1683 Antoni van Leeuwenhoek (1632–1723), Dutch biologist and microscopist, discovers different types of infusoria (minute organisms found in decomposing matter and stagnant water). He also describes several protozoa and observes the capillaries in living specimens of tadpoles and fish.

1683 The Boston Philosophical Society is founded. This is the first scientific society organized in the American colonies. Its brief existence is recorded by its founder, Increase Mather (1639–1723), who describes it as a private philosophical (scientific) society of "agreeable gentlemen" who meet every fortnight to discuss the advancement of knowledge.

1683 Joseph-Guichard Duverney (1648–1730), French anatomist, conducts investigations of the inner structure of the ear and publishes the first textbook on otology (the science of the ear and its diseases).

1683 Martin Lister (1638–1712), English zoologist, publishes an article in the *Philosophical Transactions* of the Royal Society that contains the first map to show geologic features.

1683 Thomas Sydenham (1624–1689), English physician, publishes his masterwork treatise on gout. He greatly influences the practice of internal medicine with his revival of the Hippocratic methods of observation and experience.

1684 Giovanni Domenico Cassini (1625–1712), Italian-French astronomer, discovers two satellites of Saturn, which he names Dione and Tehthys.

1684 Isaac Newton (1642–1727), English physicist and mathematician, provides the first summary exposition of his theory of gravitation in a memoir entitled "De motu corporum." He expands on it later in his 1687 *Principia*.

1684 Raymond Vieussens (1641–1715), French physician and anatomist, publishes his *Neurographia Universalis*, which contains the first description of the brain's "centrum ovale" and makes great strides in understanding all the structures of the nervous system.

1685 Edmund Halley (1656–1743), English astronomer, asks Isaac Newton (1642–1727), English scientist and mathematician, a hypothetical question involving planets and an attractive force. When Newton replies that he not only knows the answer but had calculated that and much more during the plague year of 1666, Halley encourages Newton to repeat his work once again. This eventually results in Newton's *Principia*.

1686 Edmond Halley (1656–1742), English astronomer, develops a fairly reliable formula that links the altitudes of various localities with the atmospheric pressure measured there. His altimetric formula is one of the first practical applications of the new barometric discoveries.

1686 Gottfried Wilhelm Leibniz (1646–1716), German philosopher and mathematician, publishes a paper, "Demonstratio erroris memorabilis Cartesii," attacking René Descartes' principle of the conservation of motion.

1686 Bernard le Bovier de Fontenelle (1657–1757), French author and secretary of the Académie des Sciences, publishes his *Entretiens sur la Pluralité des Mondes*, in which he theorizes about life on other worlds.

1686 The first book in English on dentistry is written by Charles Allen of Ireland. His book, *The Operator for the Teeth*, is published in Dublin.

1686 Gottfried Kirch (1639–1710), German astronomer, discovers the variability of the star Zeta Cygni. He is also one of the earliest systematic observers of comets.

1686 John Ray (1628–1705), English naturalist, publishes the first of his three-volume work *Historia Plantarum* (1686–1704). This work introduces the idea of species—groups of individual plants with similar seeds—into botany and lays the groundwork for Carl Linnaeus's modern form of systematic classification.

1686 The symptoms of chorea or St. Vitus' dance are described by English physician Thomas Sydenham (1624–1689).

1687 Denis Papin (1647–1712), French physicist, publishes a work in which he offers details on the use of steam to drive a piston in a cylinder, which eventually becomes the basic design for an early steam engine. He never builds one of his own design.

1687 Isaac Newton (1642–1727), English physicist and mathematician, publishes his *Philosphiae Naturalis Principia Mathematica*, in which he states his three laws of motion. Regarded by some as the greatest scientific work ever written, it represents the culmination of the Scientific Revolution that began with Copernicus in 1543. The *Principia* states that the entire world is subsumed under a single set of laws. They are: (1) that a body remains at rest unless it is compelled to change by a force impressed upon it; (2) that the change of motion (the change of velocity times the mass of the body) is proportional to the forces impressed; and (3) that to every action there is an equal and opposite reaction. From these laws he then deduces his law of universal gravitation. This powerful law explains the motions of the heavenly bodies as well as all of Kepler's laws. It also accounts for the precession of the equinoxes and the various irregularities in planetary motion, as well as the complex variations in the motion of the moon.

1687 Pierre Varignon (1654–1722), French mathematician, publishes his *Project d'une Nouvelle Mecanique*, which treats statics as based on the principle of moments.

1687 Isaac Newton (1642–1727), English physicist and mathematician, offers a mathematical version of Boyle's law on gases, showing how the pressure and volume of a gas are inversely proportional.

1687 Ole Rømer (1644–1710), Danish astronomer, sets up an observatory in his home and builds the first transit instrument using a telescope. Called a meridian telescope, it has a telescope mounted so that it can rotate around the axis but remain always on the meridian plane. He later adds illuminated cross-hairs and a clock that strikes the seconds.

1688 Johan Hofer (1669–1752) coins the word "nostalgia" to describe the somatic ailment provoked by homesickness.

1688 John Clayton (1657–1725), English cleric, obtains methane and recognizes its flammable nature.

1689 Antoni van Leeuwenhoek (1632–1723), Dutch biologist and microscopist, discovers rods in the retina of the eye and investigates the finer anatomy of the cornea.

1689 Gottfried Wilhelm Leibniz, German philosopher and mathematician, publishes an article in which he attempts to explain planetary motion with the idea of a fluid around the sun.

1689 Johann Kunckel (1630–1703), German chemist, writes in the second edition of his *Ars Vitraria Experimentalis* that German glass-makers are now able to manufacture opalescent glass by adding calcined bone or horn.

1689 Pierre Magnol (1638–1715), French botanist, publishes his *Prodromus Historiae Generalis Plantarum*, which is the first

attempt at a simple and rational classification of plants into families.

1689 Richard Morton (1637–1698), English physician, publishes his *Phthisiologia*, in which he makes clinical observations of lung diseases and details sixteen different types. He also gives the first published description of anorexia nervosa and mentions an hereditary factor in diabetes mellitus.

1690 Christiaan Huygens (1629–1695), Dutch physicist and astronomer, publishes his *Traite de la Lumiere*, in which he states his wave theory of light. This unpopular theory sees light as a longitudinal wave that undulates in the direction of its motion much as a sound wave does. The worth of this theory is not understood for a full century.

1690 Christiaan Huygens (1629–1695), Dutch physicist and astronomer, publishes his *Cosmotheros*, a mystical work in which he states that life forms similar to humans exist on other planets.

1690 Erasmus Warren of England publishes his *Geologia*, in which he denies that creation could have taken only six days. He also argues that the flood waters did not entirely cover Earth or radically change its topography.

1690 Johannes Hevelius (1611–1687), German astronomer, has the third and final part of his great work on astronomy published posthumously as *Prodromus Astronomiae.* It is the first work in astronomy to use coordinates with respect to the equator instead of the ecliptic. It is also the last great work of naked-eye astronomy.

1691 Bernardino Ramazzini (1633–1714), Italian physician, publishes *De Fontium Mutinensium*, which contains his diagrams explaining how artesian wells originated.

1691 Edmund Halley (1656–1742), English astronomer, writes an article in which he describes Earth's water cycle: The sun evaporates sea water, which rises to mountain heights and is condensed into rain, which falls and penetrates into Earth to emerge in springs and rivers.

1692 William Molyneux (1656–1698), Irish mathematician and astronomer, publishes his *Dioptrica Nova*, in which he introduces an improved "magic lantern" and scientifically describes it. His book is also the first English work on optics.

1692 Isaac Newton (1642–1727), English physicist and mathematician, publishes *De Natura Acidorum.*

1693 In Antrium County, Ireland, the Giant's Causeway is discovered by R. Buckley. It is a characteristic basalt (very dark, fine-grained rock of volcanic origin) formation.

1694 Jacques Bernoulli •(1654–1705), Swiss mathematician, discovers the equation of the elastic curve of a beam. This is the curve of the neutral surface of a structural member subjected to loads that cause bending.

1694 Joseph Pitton de Tournefort (1656–1708), French botanist, publishes his classic three-volume work, *Elemens de Botanique*, in Paris. It makes a major contribution to the emerging concept of genus in botany (being groups of all related species).

1694 Nicolaas Hartsoeker (1656–1725), Dutch physicist and histologist, suggests the "homunculus" idea. He says that the sperm of a bird carries a fully-developed, miniature member of its species.

1694 Rudolph Jakob Camerarius (1665–1721), German botanist, first establishes by experiment the existence of sexual reproduction of plants. He publishes his results in *Epistola...De Sexu Plantarum.*

1695 John Woodward (1665–1728), English physicist, publishes his *Essay Towards a Natural History of the Earth*, which exemplifies his orthodox religious interpretation of the Earth's history. He says the earth was dissolved and "taken all to pieces" by the flood and eventually resettled into the strata we know today.

1695 Nehemiah Grew (1641–1712), English botanist and physician, discovers magnesium sulfate in the springs at Epsom, Surrey, England, and this compound has been called "Epsom salts" ever since.

1696 Daniel Le Clerc (1652–1728), Swiss physician, publishes his *Histoire de la Médecine.* Called the "father of the history of medi-

cine," Le Clerc makes the first attempt at a synthetic survey of medical history.

1696 William Whiston (1667–1752), English mathematician, publishes his book *A New Theory of the Earth*, in which he attributes the great flood to a passing comet. Despite his religious orientation, he is one of the first to suggest a literal interpretation of the six "days" of creation.

1697 Antonio Pacchioni (1665–1726), Italian anatomist, discovers the glands in the brain's dura mater. These small bodies bear his name today.

1698 Edmund Halley (1656–1742), English astronomer, commands the sloop *Paramour Pink* on the first sea voyage undertaken for purely scientific purposes. This two-year voyage observes the variations in compass readings in the South Atlantic in order to determine accurate latitudes and longitudes for certain ports.

1699 Guillaume Amontons (1663–1705), French physicist, publishes his observations on gases. In this work on different gases he shows that each gas changes in volume by the same amount for a given change in temperature. Implied in this is the notion of absolute zero, at which gases can contract no farther.

1699 Edward Lhuyd (1660–1709), Welsh botanist and geologist, publishes his *Lithophylacii Britanici Ichnographia*, a landmark fossil catalog in which he lists and classifies over 1,700 types of fossils.

1699 Edward Tyson (1650–1708), English naturalist, publishes his pioneering work in comparative morphology and physical anthropology. His *Orang-Outang* is published in London.

1700 The Berlin Academy of Science is founded.

1700 Bernardino Ramazzini (1633–1714), Italian physician, publishes the first systematic treatment on occupational diseases. His book, *De Morbis Artificum*, opens up an entirely new department of modern medicine—diseases of trade or occupation and industrial hygiene.

1700 Construction begins on the Berlin Observatory in Germany. Actual observations from it are made in 1706.

1700 Georg Ernst Stahl (1660–1734), German chemist, publishes his *De Ortu Venarum Metalliferarum*, in which he states that mineral veins were deposited when Earth first formed and have changed little since.

1700 Giorgio Baglivi (1668–1706), Italian anatomist, publishes his *De Fibra Motrice* in Perugia. It is based on his microscopical observations and is the first book to distinguish between smooth muscle and striated muscle.

1700 Joseph Pitton de Tournefort (1656–1708), French botanist, publishes his *Institutiones rei herbariae*, which develops the binomial system and prepares the way for Linnaeus's methods.

1701 Isaac Newton (1642–1727), English physicist and mathematician, suggests that the rate of cooling of a solid is proportional to its temperature. This is later called Newton's Law of Cooling.

1701 Joseph Sauveur (1653–1716), French mathematician, first introduces the term "acoustics" for the study of sound and examines the relations of the tones of the musical scale.

1702 David Gregory (1659–1708), Scottish mathematician and astronomer, publishes his *Astronomiae Physicae et Geometriae Elementa*, which is the first astronomy text based on Newton's gravitational principles.

1702 Guillaume Amontons (1663–1705), French physicist, works on an improved thermometer and discovers that at a fixed pressure, water will always boil at the same temperature.

1702 A new type of metallurgical furnace, called a cupola furnace, that is used for making pig-iron is adopted in England. It produces a better quality iron.

1702 Antoni van Leeuwenhoek (1632–1723), Dutch biologist and microscopist, discovers hydra (a genus of small, fresh water hydrozoan polyps).

1702 Wilhelm Homberg (1652–1715), German physician, discovers boric acid, which he calls "sedative salt."

1703 Jean de Hautefeuille (1647–1724), French physicist, builds a rudimentary seismoscope

that uses drops of mercury. Although fairly crude, it is considered the first instrument built to study an earthquake's shocks.

1704 Isaac Newton (1642–1727), English physicist and mathematician, publishes his *Opticks*, a comprehensive work containing his main discoveries on the nature of light and color as well as his particle or corpuscular theory of light.

1704 Isaac Newton (1642–1727), English physicist and mathematician, speculates in his *Opticks* that crystals form when tiny particles in an evaporating liquid are forced together by mutual attraction.

1704 Antonio Maria Valsalva (1666–1723), Italian anatomist, introduces the terms "external," "middle," and "internal" to describe the anatomy of the ear in his book *De Aure Humana Tractatus.*

1704 Giacomo Filippo Maraldi (1665–1729), Italian astronomer, discovers the variability of the star R Hydrae. He is the nephew of Italian-French astronomer Giovanni Domenico Cassini (1625–1712).

1705 Francis Hauksbee (c.1666–1713), English physicist, experiments with a clock in a vacuum to determine if sound needs air to travel.

1705 John Keill (1671–1721), English mathematician, states that a lodestone's attraction is determined by the internal structure of its parts, for if that structure is altered by striking it or by fire, it will lose its magnetic powers.

1705 William Derham (1657–1735), English physicist, demonstrates that the wind can affect the velocity of the transmission of sound.

1705 Edmund Halley (1656–1742), English astronomer, first predicts that the comet he observed in 1682 would return again in roughly 75 years. He argues that comets are subject to the same gravitational laws as planets and that the comets recorded in 1456, 1531, and 1607 were in fact the same comet, but one which was in a closed but very elongated orbit about the sun and which was visible only when it came close to Earth (every 75 or 76 years). He is proven correct when the comet returns in 1758, making this one of the great achievements in theoretical astronomy.

1705 Robert Beverly (c.1673–1722) publishes in London his *History of the Present State of Virginia*, in which he describes American mineral resources soils, water supply, and physical features.

1705 Robert Henry Eliot becomes the first professor of anatomy at Edinburgh, England, and assumes the chair at an annual salary of 15 pounds.

1706 First laboratory of marine zoology is founded in Marseilles, France.

1708 Hermann Boerhaave (1668–1738), Dutch physician, publishes his *Institutiones Medicae.* As possibly the most eminent physician in Europe since Galen (c.129–c.216), he is known as the "Dutch Hippocrates." This textbook on physiology goes through a huge number of editions and translations including Arabic.

1709 Francis Hauksbee (c.1666–1713), English physicist, publishes his *Physico-Mechanical Experiments on Various Subjects*, in which he is the first to study capillary action. He makes the first accurate observations of the effects involving the attractive forces between a liquid and a solid. It is this action that causes water to rise within thin tubes and to spread over a flat surface.

1709 John Freind (1675–1728), English physician and chemist, publishes *Praelectiones Chymicae* in London; it is one of the earliest attempts to use Newtonian principles to explain chemical phenomena.

1710 Giovanni Domenico Santorini (1681–1737), Italian anatomist, discovers the muscle in the larynx that now bears his name.

1710 Henri-François Le Dran (1685–1770) and Sauveur-François Morand (1697–1773), both French surgeons, perform the first exarticulation (amputation of a limb through a joint) of the shoulder joint.

1710 The first porcelain factory in Europe opens in Germany at Meissen, near Dresden.

1711 The first patented medicine in America is "Tuscora Rice," which is hailed as a cure for tuberculosis.

1713 The Theatrum Anatomicum (a dissecting room to instruct pupils on a cadaver) is founded in Berlin.

1714 Gabriel Daniel Fahrenheit (1686–1736), German-Dutch physicist, invents the mercury thermometer—the first really accurate thermometer. His use of mercury instead of alcohol means that temperatures far above the boiling point of water and well below its freezing point can be measured (since alcohol has a low boiling point). He also invents the Fahrenheit temperature scale, in which the freezing point of water is 32 degrees and the boiling point is 212 degrees. He arrives at these by adding salt to water to find the lowest freezing point, which he calls zero.

1714 Cotton Mather (1663–1728), American cleric and writer, announces the 1705 discovery of gigantic bones (of mastodons) in Albany, New York.

1714 The British Parliament establishes a Board of Longitude with the ability to stimulate research and technology to determine longitude at sea by use of astronomical calculation and chronometer.

1715 A total eclipse is observed and recorded for the first time by a large number of coordinated observers throughout Europe. This is due largely to the efforts of English astronomer Edmund Halley (1656–1743), who organizes the international scientific effort.

1715 Antonio Vallisnieri (1661–1730), Italian zoologist, publishes his *Lezione Accademica Intorno All'Origine delle Fontane*, in which he settles the debate over the origin of springs. He says that spring water gushes from mountains because of the rain and snow that penetrate into the ground and resurface.

1715 Johannes Thomas Hensing (1683–1726) of Germany discovers phosphorous in the blood.

1716 Jean Jacques D'Ortous de Mairan (1678–1771) of France publishes his *Dissertation sur La Glace*, in which he studies ice and freezing and recognizes the cooling effect of evaporation. He also writes a section on optics.

1716 Edmund Halley (1656–1742), English astronomer, devises a method for observing transits of Venus across the disc of the sun (which would not occur until 1761) in order to determine accurately, by solar parallax, the distance of Earth from the sun.

1716 First unambiguous account of plant hybridization is given by the American writer Cotton Mather (1663–1728). He describes a case involving red and blue kernels of *Zea mays* (corn).

1717 The experimental aspects of the impact between bodies is discussed by the French physicist Edme Mariotte (1620–1684) in his *Traite de la Percussion ou Choc des Corps.* It is published posthumously in this year.

1718 Edmund Halley (1656–1742), English astronomer, discovers and demonstrates that stars actually move independently in space. His proof that stars actually change their positions shatters the traditional belief of the heavens being filled with fixed stars. He publishes his findings in an article in *Philosophical Transactions.*

1718 Etienne-François Geoffroy (1672–1731), French apothecary, publishes his *Tables des Différens Rapports*, which offers a table of affinities between various acids and alkalis or metals. Chemistry eventually accepts his prophetic concept of affinity.

1718 Stephen Hales (1677–1761), English botanist and chemist, first measures the blood pressure of a mare.

1719 Willem Jacob Storm van s'Gravesande (1688–1742), Dutch mathematician, publishes his *Physices Elementa Mathematica Experimentis Confirmata sive Introductio ad Philosopiam Newtonianam*, a highly popular work that introduces Newton's physics to the rest of Europe.

1719 John Strachey (1671–1743), English geologist, publishes *A Curious Description of the Strata Observ'd in the Coal-Mines of Mendip*, which is one of the earliest attempts at establishing a stratigraphical succession.

1720 Alexander Monro (1697–1767), English physician, is appointed the first professor of anatomy at the University of Edinburgh.

1720 Jacques Cassini (1677–1756), French astronomer, publishes his *Traite de la Grandeur et de la Figure de la Terre*, in which he completes his father's (Giovanni Domenico Cassini; 1625–1712) work. He offers measurements that support René Descartes' and his father's view that Earth is elongated at the poles.

1721 Antonio Vallisnieri (1661–1730), Italian zoologist, publishes *De Corpi Marini*, in which he states that fossils did not originate during the Great Flood but rather were from organisms that once had lived in the same places they are found fossilized, and that those places were once covered by the sea.

1722 George Graham (1675–1751), English optician and instrument maker, discovers the daily variation of magnetic declination. He finds that a magnetic needle moves according to the time of day.

1722 René-Antoine Ferchault de Réaumur (1683–1757), French physicist, publishes *L'Art de Convertir Le Fer Forgé En Acier et L'Art D'Adoucir Le Fer Fondu*, which demonstrates the importance of carbon to steel and which becomes the first scientific study of ferrous metals and the processes for working them.

1723 Georg Ernst Stahl (1660–1734), German chemist, publishes his major work, *Fundamenta Chymiae Dogmaticae et Experimentalis*, in which he develops his phlogiston theory. Although incorrect, it is the first comprehensive explanation of the phenomenon of combustion, and its popularity dominates for the next century. To Stahl, air is only the carrier of phlogiston, which he says is what is burning during combustion.

1723 The first modern English hospital medical school, Guy's Hospital, is founded in London by philanthropist bookseller Thomas Guy (1664–1724).

1724 Hermann Boerhaave (1668–1738), Dutch physician, publishes his *Elementae Chemiae*, in which he argues that heat is a fluid.

1724 Willem Jacob Strom van s'Gravesande (1688–1742), Dutch mathematician, publishes his *De Evidentia*, in which he defines the difference between physics and mathematics and upholds the autonomy of physics as a separate discipline.

1725 Bernard de Jussieu (1699–1777), French physician, becomes subdemonstrator of plants in the Jardin du Roi in Paris.

1725 Jacob Scheuchzer (1672–1733), Swiss mathematician and physician, describes the discovery of what he calls *Homo diluvili testis*. Although this fossil is really an ancient salamander,* the deeply religious Scheuchzer argues it is the remains of a child who lived before the Great Flood.

1725 John Flamsteed (1646–1719), English astronomer and first Astronomer Royal at Greenwich, publishes his massive star catalog, *Historia Coelestis*. This great work is three times as large as Tycho Brahe's, and the individual stars listed in it are located with six times greater precision. It is the first great star map of the telescopic age.

1727 Stephen Hales (1677–1761), English botanist and chemist, studies plant nutrition and measures water taken up by plant roots and released by leaves; he states that something in the air (CO_2) is converted into food and that light is necessary for this purpose. His work *Vegetable Staticks*, published this year, lays the foundation for plant physiology.

1728 Francesco Bianchini (1662–1729), Italian astronomer, publishes his *Hesperi et Phosphori Nova Phaenomena*, in which he estimates a rotational period for Venus of 24 and 1/3 days. This value is actually ten times less what it should be, but the planet's cloud cover prevents accurate measurement until the invention of radar.

1728 Jacopo Bartolomeo Beccaria (1682–1766), Italian physician, discovers gluten in wheat flour. This is the first protein substance of plant origin to be found.

1729 Pierre Bouguer (1698–1758), French physicist, publishes his *Essai d'Optique sur la Gradation de la Lumiere*, in which he makes some of the earliest measurements in astronomical photometry. He also investigates the absorption of light in the atmo-

sphere and formulates what comes to be known as Bouguer's law. This concerns the attenuation of a light beam upon passage through a transparent medium.

1729 Pieter van Musschenbroek (1692–1761), Dutch physicist, builds the first crude testing machine using a steelyard. This is a form of balance in which the object is suspended from the shorter arm of a lever, and its weight is found by moving a counterpoise along the arm to produce equilibrium. He also uses the term "physics" for the first time in place of "natural philosophy."

1729 Stephan Gray (c.1696–1736), English chemist, discovers electrical conduction. He notes that when a long glass tube is electrified by friction, the corks at each end also become charged. He states that electricity or what he calls electric fluid has traveled from the glass to the corks. This is now called conduction.

1729 Eustachio Manfredi (1674–1739), Italian mathematician and astronomer, publishes his *De Annuis Inerrantium Stellarum Aberrationibus*, in which he announces his discovery of the annual aberration of fixed stars. This is the first use of the term aberration. James Bradley, (1693–1762), English astronomer, also correctly explains this phenomenon the same year.

1729 James Bradley (1693–1762), English astronomer, discovers the phenomenon he calls the "aberration of light." This theory assumes that light does not travel instantaneously but has a finite or given velocity. It also says that Earth itself is moving around the sun at a given orbital speed. Together, this explains the apparent displacement of a star toward the direction in which Earth is moving. Bradley's discovery becomes the first observational proof of Galileo's argument that Earth is moving, as well as confirmation of Rømer's argument that light has a finite velocity.

1730 Pieter van Musschenbroek (1692–1761), Dutch physicist, argues for the autonomy of physics from mathematics, saying its laws are revealed by the senses, and that it can do without mathematics altogether.

1730 René Antoine Ferchault de Réaumur (1683–1757), French naturalist and physicist, develops a thermometer independently of Fahrenheit and establishes what comes to be known as the Reaumur temperature scale. This system has 0 degrees as the freezing point of water and 80 degrees as the boiling point of water at normal atmosphere pressure.

1730 Stephen Gray (c.1696–1736), English chemist, demonstrates that the human body can be an electrical conductor and harmlessly electrifies a boy using silk threads.

1730 John Bartram (1699–1777), American botanist, starts the first botanical garden in America. He began assembling native plants at his farm near Philadelphia, Pennsylvania, in 1728. His son, William, also makes botanical contributions.

1730 Stephen Hales (1677–1761), English botanist and chemist, discovers that the reflex movements of a frog's legs depend upon the spinal cord.

1731 John Hadley (1682–1744), English instrument maker, invents the reflecting octant, the first sextant-type instrument able to measure the position of the heavenly bodies from the deck of a ship. It is also claimed that the American optician Thomas Godfrey (1704–1749) simultaneously invented the same device.

1731 The Académie Royale de Chirurgie is founded in France. Surgery finally begins to achieve some dignity as a profession.

1732 Pierre Louis Moreau de Maupertuis (1698–1759), French mathematician, publishes his *Discours sur la Figure des Astres*, in which he predicts the shape of Earth using Newtonian mechanics.

1732 Hermann Boerhaave (1668–1738), Dutch physician, publishes his *Elementa Chemiae*. Its comprehensiveness makes it the most popular chemical textbook for many decades. It serves chemistry as a great teaching book and presents a concise outline of all chemical knowledge.

1732 Philadelphia Hospital in Pennsylvania is founded.

1733 Charles François de Cisternay Du Fay (1698–1739), French physicist, discovers that two electrified objects sometimes attract and sometimes repel each other. He notes that their means of being charged seems to be the difference and states that there are two types of electricity—"resinous" and "vitreous." He formulates the basic electrical law that "like charges repel and unlike charges attract." Later, American statesman and scientist Benjamin Franklin (1706–1790) calls these two types of electricity "positive" and "negative."

1733 Johann Heinrich Winckler (1703–1770), German physicist, produces an improved frictional electrical machine and is the first to suggest the use of conductors as a means of protection against lightning.

1733 Georg Brandt (1694–1768), Swedish chemist, publishes the first complete study of arsenic and its compounds.

1734 Emanuel Swedenborg (1668–1772), Swedish scientist, philosopher, and mystic, publishes his *Principia Rerum Naturalium*, in which he offers a mathematical and mechanical explanation of the origin, development, and working of the universe.

1734 The first American to graduate from a medical school (University of Leiden) is William Bull.

1734 René Antoine Ferchault de Réaumur (1683–1757), French physicist, publishes the first book of his massive, six-volume study on insects (1734–1742). He emphasizes the practical aspects of beekeeping and designs the first egg incubator. His work is titled *Mémoires pour Servir a L'Histoire des Insectes.*

1735 Louis Bertrand Castel (1688–1757), French physicist and mathematician, publishes an article describing his "ocular harpsichord." He uses this instrument and offers a scheme for making colors and musical tones correspond.

1735 The Boston Medical Society is first organized.

1735 Carl Linnaeus (1707–1778; also known as Carolus Linnaeus or Carl von Linné), Swedish botanist, publishes *Systema Naturae*, a methodical and hierarchical classification of all living things. He develops the binomial nomenclature that will be used in classifying plants and animals. In this system, each type of living thing is given first a generic name (for the group to which it belongs), and then a specific name for itself. He classifies minerals as well as living organisms, according to their crystalline shapes, both external and internal, and then into species, genera, and classes.

1735 Gaspar Casal (1679–1759), Spanish physician, gives the earliest description of the dietary deficiency disease pellagra.

1735 Georg Brandt (1694–1768), Swedish chemist, discovers cobalt, which he later isolates in 1743. He becomes the first person to discover a metal that was entirely unknown to the ancients.

1735 Johann Georg Gmelin (1709–1755), German explorer, discovers permafrost during an expedition to Siberia.

1736 Leonhard Euler (1707–1783), Swiss mathematician, publishes his *Mechanica; sive, Motus Scientia Analytice Exposita*, a work of mathematical physics in which he maintains that the principles of mechanics are necessary truths.

1736 Antonio de Ulloa (1716–1795), Spanish mathematician, introduces platinum from South America into Europe and later writes an accurate description of it.

1736 Claudius Amyand (c.1680–1740), English surgeon, performs the first successful appendectomy.

1736 Henri-Louis Duhamel du Monceau (1700–1782), French chemist and botanist, first uses the term "base" to indicate those substances that combine with acids to form salts. He is also the first to make a distinction between soda and potash (potassium).

1737 *Bybel der Natuure* by Dutch naturalist Jan Swammerdam (1637–1680) is published 100 years after his birth. With the rediscovery and publication by the Dutch physician Hermann Boerhaave (1668–1738) of this massive work, Swammerdam becomes recognized as the founder of modern entomology (the study of insects).

1737 Albrecht von Haller (1708–1777), Swiss physiologist, first points out the function of bile in the digestion of fats.

1737 An earthquake in Calcutta, India, kills an estimated 300,000 people.

1737 First chair of chemistry is established at the faculty of medicine in Bologna, Italy, and is assigned to the German chemist Johann B. Becher (1635–1682).

1738 Daniel Bernoulli (1700–1782), Swiss mathematician, publishes his *Hydrodynamica*, which is a comprehensive work on fluid flow or hydrodynamics. In it he describes what comes to be called Bernoulli's principle—that as the velocity of fluid increases, its pressure decreases. This marks the beginning of theoretical hydrodynamics.

1738 Daniel Bernoulli (1700–1782), Swiss mathematician, publishes his *Hydrodynamica*, containing his kinetic theory of gases. This treatise becomes a work of major importance in both physics and chemistry. This is the first attempt at an explanation of the behavior of gases which, he assumes, are composed of a vast number of tiny particles.

1738 George Matthias Bose (1710–1761), German physicist, uses an isolated conductor to improve the generation of electricity in a frictional machine.

1738 Pierre Louis Moreau de Maupertuis (1698–1759), French mathematician, publishes his *Sur la Figure de la Terre* which details the results of an expedition to Lapland to measure the curvature of Earth. He offers measurements that confirm Earth is flattened at the poles.

1739 Leonhard Euler (1707–1783), Swiss mathematician, publishes his *Tentamen Novae Theoriae Musicae*, a work on vibrating strings, in which he formulates a new theory of music.

1739 Johann Andreas Cramer (1710–1777), German metallurgist, publishes his *Elementa Artis Docimasticae*, which is the first textbook on assaying and chemical analysis. It also contains the first description of the use of a blowpipe.

1739 John Winthrop (1714–1779), American mathematician and astronomer, writes his *Notes on Sunspots*, which records the first scientific solar observations made in the colony of Massachusetts. He later publishes his lectures on comets.

1739 Sauveur-François Morand (1697–1773), French surgeon, performs the first excision of a hip joint.

1740 George Martine (1702–1741), Scottish physician, publishes his book on animal heat and shows that the amount of heat contained in an object is not related to its volume.

1740 Abraham Trembley (1710–1784), Swiss naturalist, discovers the regeneration process when he cuts hydras into several pieces, which then produce new individuals.

1740 Anders Celsius (1701–1744), Swedish astronomer, becomes the first to try to determine the magnitude of the stars by measuring the intensity of their light using a device other than the human eye. He also studies the aurora borealis and is the first to associate it with changes in Earth's magnetic field.

1740 Anton Lazzaro Moro (1687–1764), Italian naturalist, publishes his *De Crostacei e Degli Altri Marini Corpi*, in which he classifies mountains, discusses marine fossils, and shows a profound understanding of Earth's dynamic history. It becomes an important book to geology.

1740 The first large chemical industry is founded by Joshua Ward (1685–1761) at Richmond, England, near London to produce sulfuric acid. The acid is obtained by heating sulfur with saltpeter in iron capsules and condensing the vapor the reaction produces in large balls. Chemistry will prove to be the science most directly tied to industry.

1742 Anders Celsius (1701–1744), Swedish astronomer, applies a new scale to his thermometer by dividing the temperature difference between the boiling and freezing points of water into an even hundred degrees (with zero at the freezing point). His system becomes known as the centigrade scale and eventually is adopted internationally by scientists.

1742 Andreas Gordon (1712–1751), Scottish physicist, abandons the use of glass globes to produce electricity and is the first to use a glass cylinder, which he is able to rotate rapidly. He achieves 680 revolutions a minute with his new device and can thus generate enough electricity to badly shock a person.

1742 Colin Maclaurin (1698–1746), English mathematician, publishes *Treatise of Fluxions*, which supports Newton and criticizes the ideas of Leibniz.

1742 John Theophile Desaguliers (1683–1744), French-English physicist, publishes *Dissertation Concerning Electricity*, in which he is the first to use the word "conductor" to describe those substances that allow electricity to flow. He also names nonconducting materials "insulators."

1742 Anton Svab (1703–1768) of Sweden, also known as Swab, distills zinc from the alloy calamine.

1743 Alexis Claude Clairault (1713–1765), French mathematician, publishes his *Théorie de la Figure de la Terre Tirée des Principes de l'Hydrostatique*, in which he describes the shape of Earth. He shows how the shape of Earth can be calculated experimentally by measuring the force of gravity at different points through the timing of pendulum swings. He definitively discusses a rotating body in the shape of Earth and how it acts under the influence of gravity and centrifugal force. He says its shape is determined by a sort of water balance of masses that is subject to the centrifugal force of rotation and the effects of gravity.

1743 Jean Antoine Nollet (1700–1770), French physicist, publishes *Lecons de Physique Experimentale*, which is based on his very popular lecture course. These lectures on electricity are so popular that he often gives them at the royal court in Versailles.

1743 Jean le Rond D'Alembert (1717–1783), French mathematician, publishes his *Traite de Dynamique*, in which he expands on Newton's laws of motion. He argues that mechanics is the highest rational science because its principles are necessary truths.

1743 The American Philosophical Society is founded by American statesman and inventor Benjamin Franklin (1706–1790). It becomes the first permanent scientific organization in the American colonies.

1743 Christopher Packe (1686–1749), English geologist, produces "A New Philosophico-chrorographical Chart of East Kent," which maps the geology of East Kent, England. This is considered to be the first geological map.

1743 Jean-Philippe Loys de Cheseaux (1718–1751) of Switzerland publishes a work on a comet he observes and includes an estimate of the distance to first magnitude stars. Although his final figure is incorrect, his attempt at calculating absolute stellar distances is very advanced

1744 Christian Friedrich Ludolf of Germany first demonstrates the ignition of inflammable substances by an electric spark.

1744 Jean le Rond D'Alembert (1717–1783), French mathematician, publishes his *Traite de l'Equilibre et du Mouvement des Fluides*, in which he uses his equilibrium principle to describe the motion of fluids.

1744 Pierre Louis Moreau de Maupertuis (1698–1759), French mathematician, publishes a paper titled "Accord de differentes lois de la nature qui avaient jusqu'ici paru incompatibles," in which he first states the principle of least action. This states that physical laws include a rule of economy in which action is a minimum.

1744 César François Cassini (1714–1784), French astronomer and a member of the famous Cassini family of astronomers, conducts the triangulation of France. This is the first national geographic survey ever done and results in the first modern survey map.

1744 Leonhard Euler (1707–1783), Swiss mathematician, publishes his *Theoria Motuum Planetarum et Cometarum*, in which he calculates planetary orbits and applies his mathematics to astronomy. In this first analytical work on planetary motion,

he is the precursor of both Joseph Louis Lagrange (1736–1813) and Pierre-Simon Laplace (1749–1827) and actually begins the study of celestial mechanics.

1745 Christian Gottfried Kratzenstein (1723–1795), German physician, first uses electricity to relieve muscle sprains.

1745 Ewald Georg von Kleist (c.1700–1748), German inventor, discovers what comes to be known as the "Leyden jar." He discovers this method of storing static electricity before Musschenbroek, but the news from Musschenbroek spreads more rapidly throughout the scientific community.

1745 Charles Bonnet (1720–1793), Swiss naturalist, publishes his *Traité d'Insectologie*, in which he details his discovery of parthenogenesis in aphids (by which they reproduce by the development of an unfertilized gamete).

1745 The first (bituminous) coal mine in North America is opened in Richmond, Virginia. This deposit was known as early as 1673.

1746 Gowan Knight (1713–1772), English natural philosopher, is the first to make very powerful, artificial steel magnets.

1746 Jean Antoine Nollet (1700–1770), French physicist, is the first in France to experiment with the new Leyden jar.

1746 John Bevis (1693–1771), English physician and astronomer, is the first to strengthen the charge of a Leyden jar by applying a coating of tinfoil or sheet-lead. He is also the first to observe that the charge increases as larger jars are used.

1746 John Ellicott of England suggests a method of estimating the exact force of the electrical charge contained in a Leyden jar by its power to raise a weight in one scale of a balance while the other is held over and attracted by the electrified body.

1746 Leonhard Euler (1707–1783), Swiss mathematician, argues against the particle theory of light and suggests correctly that light has a wave form, and that color depends on the length of that wave.

1746 Louis Guillaume Le Monnier (1717–1799), French naturalist, is the first to recognize that the air or atmosphere is almost constantly charged.

1746 William Watson (1715–1787), English physician and botanist, publishes his *Experiments on the Nature of Electricity*, in which he is the first to investigate the passage of a current through rarified gas and to discover that conductivity increases.

1746 Jean Etienne Guettard (1715–1786), French geologist, writes an article in which he declares that the mineralogical formations on the opposing French and English coasts are identical, indicating they were once part of the same geological system. This article also contains the first true geologic or mineralogic map, as he ignores political boundaries in his drawing and shows how the formations or "bandes" are connected under the Channel.

1746 Jean-Paul de Rome d'Ardène (1689–1769) of France publishes *Traité des Ranoncules*, which becomes the first work entirely on ranunculuses or plants of the Crowfoot family. The buttercup is a member of this plant family.

1746 Johann Heinrich Pott (1692–1777), German chemist and mineralogist, publishes his *Lithogeognosia*, in which he uses the word "geognosy." Derived from the Greek word "gnosis" for knowldege, it later comes to be used by the German geologist Abraham Gottlob Werner (1750–1817) to describe his scientific study of Earth and to distinguish it from the geology of his time, which he says is not based on factual knowledge.

1746 Pehr Wilhelm Wargentin (1717–1783), Swedish astronomer, publishes tables of Jupiter's satellites that are far more accurate than those of his predecessors.

1746 Pierre-Louis Moreau de Maupertuis (1698–1759), French mathematician, publishes his *Venus Physique* and foresees the chromosomal basis of heredity. He rejects the alternative (preformation) theories of ovism and spermism on the grounds that children often resemble both parents.

1746 Pieter van Musschenbroek (1692–1761), Dutch physicist, invents the "Leyden jar,"

which is the first really efficient device for storing static energy. While experimenting at the University of Leyden, he finds that a glass vial or jar, partly filled with water, whose mouth is closed by a cork through which a nail or wire dips into the water, will store static electricity. It releases its charge when the wire is touched. This capture of electricity allows it to be studied at length. This invention follows a similar discovery by Ewald Georg von Kleist (c.1700–1748) of Germany the previous year, though Musschenbroek's invention is more highly publicized in the scientific community. The Leyden jar is also a prototype of the modern capacitor.

1747 Alexis Claude Clairault (1713–1765), French mathematician, publishes his *Théorie de la Lune*, which contains the first approximate solution to the "three-body problem" (concerning the interaction between three different masses in space).

1747 Andreas Sigismund Marggraf (1709–1782), German chemist, discovers that beets produce the same sugar as sugarcane. This leads to the development of the sugar industry.

1747 Bernhard Siegfried Albinus (1697–1770), German anatomist, publishes the first of three books (1747–1753) on human anatomy. The copperplate engravings are unsurpassed in both their accuracy and beauty.

1747 Johan Gottschalk Wallerius (1709–1785), Swedish mineralogist, publishes his *Mineralogia*, which becomes the first major treatise on this subject. He examines the chemical properties of minerals as well as their external characteristics.

1748 Benoît de Maillet (1656–1728), French geologist, has his life's work published twenty years after his death. Titled *Telliamed*, which is his name spelled backwards, it contains a new and radical theory of Earth. It totally ignores any role for a deity and offers instead the physical idea of a cyclical transformation of Earth and planets into burning stars and cool, habitable lands.

1748 Gowan Knight (1713–1772), English natural philosopher, publishes a book in which he discounts the reality of matter and states that the forces of attraction and repulsion account for all observed phenomena.

1748 Mikhail Vasilievich Lomonosov (1711–1765), Russian chemist and writer, publishes several works in which he anticipates the work of Antoine-Laurent Lavoisier (1743–1794) and suggests the law of conservation of matter.

1748 James Bradley (1693–1762), English astronomer, publishes an article in which he announces his discovery of the nutation (small, periodic shifts) of Earth's axis. He attributes this to the gravitational pull of the moon. Although he had discovered this in 1729, he studies the problem for nineteen years and waits until he has gathered sufficient evidence to prove it.

1748 Jean-Antoine Nollet (1700–1770), French physicist, discovers osmosis or osmotic pressure while experimenting with water diffusing into a sugar solution through a membrane.

1749 Jean Jallabert (1712–1768), Swiss physicist, demonstrates that ice is a conductor of electricity.

1749 John Canton (1718–1772), English physicist, experiments with electricity and prepares an artificial magnet.

1749 Georges-Louis Leclerc Buffon (1707–1788), French naturalist, publishes the first volume of his forty-four volume work, *Histoire Naturelle* (1749–1804). He applies his evolutionary views to Earth's history and suggests that it may have been in existence for as much as 75,000 years. He also suggests that it may have been created by a massive collision of a comet with the sun.

1749 Jean le Rond D'Alembert (1717–1783), French mathematician, publishes his mathematical demonstration proving that Earth's nutation is due to the influence of the moon. For the first time, these regular changes in Earth's orientation are explained mathematically.

1749 Jean-Baptiste Sénag (1693–1770), French physician, begins the study of cardiology

as an independent discipline within the field of medical pathology with his study titled *Traité de la Structure du Coeur.*

1749 Pierre Bouguer (1698–1758), French mathematician and hydrographer, publishes *La Figure de la Terre*, in which he makes the first attempt to measure the gravity of Earth with a plumb line.

1750 John Michell (1724–1793), English geologist, publishes *Treatise on Artificial Magnets*, in which he anticipates Charles Augustin de Coulomb (1736–1806) and explains his discovery of the inverse-square law for repulsive forces of magnetism. He also invents a torsion balance before Coulomb.

1750 First complete account of platinum and its properties appears in *Philosophical Transactions.* This metal was known by the natives of South America, and knowledge of it had made its way to Europe by the mid-sixteenth century.

1750 The first substantial experiments with platinum are conducted by English physician William Brownrigg (1711–1800) and William Watson (1715–1787).

1750 Johan Tobias Mayer (1723–1762), German mathematician and astronomer, maps the major mountains of the moon.

1750 Nicolas-Louis de Lacaille (1713–1762), French astronomer, begins his direction of a four-year expedition to the Cape of Good Hope to obtain an accurate figure for the Moon's parallax in combination with the observations of a colleague in Berlin. From his observations he later (1763) prepares a catalog of nearly 2,000 southern stars as well as an extensive star map of that region.

1750 Thomas Wright (1711–1786), English astronomer, offers a God-centered model of the universe that includes a perceptive way of picturing the Milky Way. He reasons that the Milky Way is a group of stars as they appear in a flattened system. This is the first time that stars are seen as existing in a flattened, rotating galaxy. It is also considered to be the first modern cosmological theory.

1751 Benjamin Franklin (1706–1790), American statesman and scientist, publishes the first of his two-volume work *Experiments and Observations on Electricity Made at Philadelphia in America.* In this work he formulates a theory of general electrical "action," also called his single fluid theory of electricity. His theory is adopted as are several of the terms and concepts he introduces, like positive and negative charge.

1751 Axel Fredrik Cronstedt (1722–1765), Swedish chemist, discovers nickel.

1751 Ferdinand VI (1713–1759), king of Spain, issues a decree requiring notification of all cases of tuberculosis, disinfection of premises, and burning of personal effects after death.

1751 Robert Whytt (1714–1766), Scottish physician, gives the first demonstration that the contraction of the eye's pupils in response to light is a reflex action (known as Whytt's reflex).

1751 Robert Whytt (1714–1766), Scottish physiologist, publishes his *The Vital and Other Involuntary Motions of Animals*, in which he gives the first clear description of what is later called reflex action.

1752 Jean le Rond D'Alembert (1717–1783), French mathematician, publishes a paper in which he attempts to reduce all problems concerning the resistance of fluids to general laws on equilibrium.

1752 Anton Friedrich Busching (1724–1793), German geographer, publishes the first of eleven volumes of his *Neue Beschreibung.* Six of these volumes focus on European geography and lay the foundation for modern statistical geography. His work helps develop a scientific basis for the study of geography by stressing statistics over descriptive writing.

1752 Henrik Theophilus Scheffer (1710–1759), Swedish chemist, publishes a detailed description of platinum and its properties and shows that it is a distinct and separate metal.

1752 John Pringle (1707–1782), Scottish physician, founds modern military medicine with the publication of his *Observations on the Diseases of the Army.* He lays down the

basic principles for military sanitation, and his book's advice is applied to better sanitation in jails, hospitals, ships, barracks, mines, and other institutions.

1752 René-Antoine Ferchault de Réaumur (1683–1757), French physicist and physiologist, studies the physiology of digestion and obtains gastric juice.

1752 Théophile de Bordeu (1722–1776), French physician, publishes his pioneering work on glands. In his *Recherches Anatomiques sur les Différentes Positions des Glandes et sur leur Action*, he recognizes that gland secretions somehow influence other parts of the body.

1752 Benjamin Franklin (1706–1790), American statesman and scientist, flies a kite carrying a pointed wire into a thunderstorm and attempts to test his theory that atmospheric lightning is an electrical phenomenon similar to the spark produced by an electrical frictional machine. To the kite he attaches a silk thread with a metal key at the end, and as lightning flashes, he puts his hand near the key, which sparks just as a Leyden jar would. He proves his point in this extremely dangerous experiment.

1753 Giovanni Battista Beccaria (1716–1781), Italian physicist, publishes his *Dell'Elettricismo Artificiale e Naturale*, in which he summarizes all known electrical experiments in light of Franklin's new unitary theory.

1753 John Canton (1718–1772), English physicist, publishes a paper in which he uses Franklin's theory to argue that bodies emit and absorb electrical fluid.

1753 James Lind (1716–1794), Scottish physician, first publishes his *Treatise of the Scurvy*. This vitamin-deficiency disease, which killed more sailors on long voyages than did battle with the enemy, was finally eliminated in the British Navy some years after Lind's book. The Navy's practice of giving lime juice to their crews resulted in British sailors being called "limeys."

1753 Leonhard Euler (1707–1783), Swiss mathematician, publishes his *Theoria Motus Lunae*, in which he mathematically analyzes the motions of the moon. This forms the basis of Johann Tobias Mayer's new tables.

1753 Georg Wilhelm Richmann (1711–1753), Swedish physicist, is struck dead at St. Petersburg, Russia, while attempting to conduct Benjamin Franklin's kite experiment during an electrical storm.

1754 Guillaume-Francois Rouelle (1703–1770), French chemist, begins a series of lectures at the Jardin du Roi that are attended by James Hutton • (1726–1727), Denis Diderot (1713–1784), Nicolas Desmarest (1725–1815), Antoine-Laurent. Lavoisier, and many others. His dynamic, stimulating talks focus on mineralogy and stress the importance of chemistry in mineralogy. His lectures are the main inspiration for most of the French, and some of the British and German, geology of the second half of the eighteenth century.

1754 Joseph Black (1728–1799), Scottish chemist, proves by quantitative experiments the existence of carbon dioxide, which he calls "fixed air." His proof is contained in his thesis done for his medical degree, and two years later he openly publishes the results.

1754 Pierre-Louis Moreau de Maupertuis (1698–1759), French mathematician, suggests that species transform over time.

1755 Leonhard Euler (1707–1783), Swiss mathematician, publishes his *Principes Generaux de l'Etat d'Equilibre des Fluides*. In this work on the equilibrium of fluids, he analyzes the behavior of a fluid under the effects of all types of forces.

1755 Leonhard Euler (1707–1783), Swiss mathematician, publishes his *Principes Generaux du Movement des Fluides*, in which he points out the difficulties involved in attaining a complete understanding of the motion of fluids.

1755 Immanuel Kant (1724–1804), German philosopher, publishes his physical view of the universe, titled *General History of Nature and Theory of the Heavens*. It contains three important astronomic "anticipations" or ideas that are later fleshed out

and proven by others. First, he describes the nebular hypothesis; second, he suggests the Milky Way is a lens-shaped collection of stars and that other such "island universes" exist; and third, he suggests tidal friction slows the rotation of Earth. This is the first really scientific hypothesis on the formation of the solar system.

1755 Johann Tobias Mayer (1723–1762), German mathematician and astronomer, publishes his lunar tables using Euler's data. These tables are later used by the British Admiralty in 1770 and greatly assist them in determining longitude at sea.

1755 An earthquake devastates and destroys much of Lisbon, Portugal, and is felt in most of Europe. This dramatic event stimulates much geological interest and results in a flood of religious sermonizing and some real scientific work.

1755 John Winthrop (1714–1779), American astronomer, offers a scientific analysis of earthquakes in his lectures at Harvard University. New England experiences an earthquake this year, and unlike Winthrop, most commentaries are about its theological implications.

1755 Lewis Evans (1700–1756), American cartographer, publishes *An Analysis of a General Map of the Middle British Colonies in America* which, in map and text, describes the geology of eastern North America. This is one of the very early works on American geomorphology.

1755 The Abbé Charles-Michel de l'Epée (1712–1780) founds the first school for deaf-mutes in Paris.

1756 Franz Ulrich Theodosius Aepinus (1724–1802), German mathematician and physicist, makes the first scientific examination of the electric properties of a tourmaline crystal. He shows that a temperature between 99 and 212 degrees Fahrenheit is necessary for its attractive powers.

1756 John Canton (1718–1772), English physicist, begins three years of careful weather observations and finds that on days when the aurora borealis is very noticeable, a compass needle becomes irregular. This is the first observation of what comes to be known as magnetic storms.

1756 William Cullen (1710–1790), Scottish physician and chemist, publishes a paper titled "Of the Cold Produced by Evaporating Fluids and Some Other Means of Producing Cold," in which he studies the phenomenon of evaporation and its cooling effect.

1756 Johann Gottlob Lehmann (1719–1767), German mineralogist, publishes *Versuche einer Geschichte von Flotz-Gebrugen*, in which he classifies mountains and establishes his theory of their origins. This work lays the foundation of stratigraphic classification and spurs local geology or the investigation of specific sites.

1756 Joseph Black (1728–1799), Scottish chemist, publishes his paper "Experiments upon Magnesia Alba, Quicklime, and Some Other Alcaline Substances," in which he describes his discovery of carbon dioxide. This is regarded as the first work on quantitative chemistry.

1757 Albrecht von Haller (1708–1777), Swiss physiologist, publishes the first volume of his eight-volume *Elementa Physiologiae Corporis Humani* (1757–1766) and distinguishes irritability or inherent muscular force from nerve or nervous force. This encyclopedic work marks the beginning of modern physiology.

1757 Alexander Monro (1697–1767), English physician, distinguishes between the lymphatic and the circulatory systems.

1757 Alexis Claude Clairault (1713–1765), French mathematician, obtains the first reasonably accurate figures for the mass of Venus and the moon. Although his estimate for Venus is somewhat too small (two-thirds Earth) and too large for the moon (one sixty-seventh), they are the closest anyone has yet to offer.

1757 Mikhail Vasilievich Lomonosov (1711–1765), Russian chemist and writer, publishes his *Oratio de Generatione Metallorum a Terre Motu*, which offers a modern view of the geological nature of past phenomena by taking into account the gradual

and imperceptible effects as well as catastrophic ones.

1758 Ruggero Giuseppe Boscovich (1711–1787), Croatian astronomer and mathematician, publishes his *Philosophiae Naturalis Theoria Redacta ad Unicam Legem virium in Natural Existentium*, in which he rejects the corpuscular theory of matter and proposes a "dynamistic" theory. He says that matter is made up of perfectly indivisible physical points that exert a force of attraction or repulsion on each other depending on their distances.

1758 Axel Fredrik Cronstedt (1722–1765), Swedish mineralogist, first introduces the blowpipe technique for analyzing ores. The mouth blowpipe is a conical brass tube curved at the small end and terminating in a round orifice. By placing a substance in the flame of a blowpipe, information is obtained about its general nature by the changes it undergoes in the flame and the residue that remains after burning.

1758 Axel Fredrik Cronstedt (1722–1765), Swedish mineralogist, publishes his *Essai d'une Nouvelle Minéralogie*, in which he begins a classification of minerals not only according to their appearance but also according to their chemical structure. He notes four kinds of minerals: earths, metals, salts, and bitumens. This is an important development.

1758 Tenth and most important edition of Carl Linnaeus's *Systema Naturae* is published.

1758 Halley's Comet is sighted. The returning comet is first seen during this month by the German amateur observer Johann Georg Palitsch and passes its perihelion on March 13, 1759, remaining visible until June 1759. It proves Halley correct and is an unequivocal confirmation of the Newtonian system.

1759 Franz Ulrich Theodosius Aepinus (1724–1802), German mathematician and physicist, publishes his *Tentamen Theoriae Electricitatis et Magnetismi*, which is one of the most original and important books in the history of electricity. It is the first reasoned exposition of electrical phenomena based on action-at-a-distance.

1759 Bernard de Jussieu (1699–1777), French physician, is invited by French King Louis XV (1710–1774) to develop a botanical garden at the Petit Trianon garden at Versailles. Jussieu creates a living illustration of his natural classification system.

1759 Edward Hyde (1609–1674) of England describes angina pectoris suffered by his father. This is the first recorded case of this heart disease, which causes chest pain because of an oxygen deficiency.

1759 Giovanni Arduino• (1714–1795), Italian mining engineer, originates the classification of rocks into four divisions (primary, secondary, tertiary, and quaternary) according to their composition.

1759 Kaspar Friedrich Wolff (1733–1794), German physiologist, publishes *Theoria Generationis* (Theory of Generation), which argues that generation occurs by epigenesis, that is, the gradual addition of parts. This book marks the beginning of modern embryology.

1760 Ebenezer Kinnersley (1711–1778), English-American experimenter, demonstrates that heat can be produced by electricity.

1760 Johann Heinrich Lambert (1728–1777), German mathematician, publishes his *Photometria*, in which he is the first to devise methods for measuring light intensities accurately.

1760 Johann Tobias Mayer (1723–1762), German astronomer, is the first to state that magnetic action follows the law of inverse squares.

1760 Leonard Euler (1707–1783), Swiss mathematician, publishes his *Theoria Motus Corporum Solidorum seu Rigidorum*, which is a mathematization of the problems of the mechanics of rigid bodies.

1760 Governor Arthur Dobbs of North Carolina discovers a Venus Flytrap growing there and sends a description to English biologist Peter Collinson (1694–1768), who is a friend and colleague in London of the American statesman and scientist Benjamin Franklin (1706–1790).

1760 In his book on plant sexuality, Carl Linnaeus (1707–1778; also known as Carolus

Linnaeus), Swedish botanist, discusses hybrids as the originators of new species.

1760 Johann Heinrich Lambert (1728–1777), German mathematician, publishes his study of light reflections titled *Photometria*. In this work he uses the word "albedo" to describe the fraction of light reflected diffusely by a body, and the term is still used in astronomy to represent the reflectivity of planetary bodies.

1760 John Michell (c.1724–1793), English astronomer, publishes a long article in which he offers his theories on earthquakes. His work is perceptive, as he states that earthquakes are partly tremulous but that they also move the earth partly by waves or vibrations which succeed one another. He also says that earthquakes uplift the strata as well as fracture and rearrange it. He considers all the known ideas about earthquakes and evaluates each according to known facts.

1760 Nicolas Desmarest (1725–1815), French geologist, writes in an article that running water can remove beds of strata and that valleys can be formed by the streams running through them.

1761 First veterinary school is established at Lyons, France.

1761 Giovanni Battista Morgagni (1682–1771), Italian anatomist, publishes his great *De Sedibus et Causis Morborum per Anatomen Indagatis*, which founds pathologic anatomy. Based on 640 dissections Morgagni had performed, this book makes pathology a genuine branch of modern science.

1761 Johann Heinrich Lambert (1728–1777), German mathematician, publishes his ideas that the Milky Way might be a visual effect produced by a lens-shaped conglomeration of thousands of stars. He is unaware of both Thomas Wright and Immanuel Kant's similar suggestions.

1761 Joseph-Nicolas Delisle (1688–1768), French astronomer, is the first astronomer to take seriously Edmund Halley's suggestion of using a transit of Venus to determine the scale of distances in the solar system. He applies that method during this year by organizing a worldwide study of that phenomenon.

1761 Joseph Leopold Auenbrugger (1722–1809), Austrian physician, first describes his percussion method, which becomes a major contribution to the diagnosis and prognosis of diseases of the chest. Ever since, doctors use his thumping-on-the-chest method to diagnose the condition of a patient's chest.

1761 Mikhail Vasilievich Lomonosov (1711–1765), Russian chemist and writer, is the first to infer that Venus has an atmosphere. He observes what he believes to be its atmosphere during its transit across the sun this year.

1761 Expeditions based at the Cape of Good Hope (South Africa), Newfoundland, and St. Helena (South Atlantic island) observe and record the solar transit of Venus. This rare phenomenon occurs twice in an eight-year period only every century

1762 Franz Ulrich Theodosius Aepinus (1724–1802), German mathematician and physicist, publishes his *Receuil de Differents Memoires sur la Tourmaline*, which is devoted to the study of pyroelectricity. This is the development of opposite electrical charges on different parts of a single crystal when it is subjected to a change in temperature.

1762 Johann Georg Sulzer (1720–1779), Swiss physicist, precedes Luigi Galvani (1737–1798) and notes the bitter taste produced by two different metals connected by a wire.

1762 Paolo Frisi (1728–1784), Italian mathematician and physicist, publishes his *Del Modo di Regolare I Fiumi, e I Torrenti*, which becomes the most used book on hydraulics of its time.

1762 The first medical library in the American colonies is founded at Pennsylvania Hospital.

1762 Georg Christian Fuchsel (1722–1773), German geologist, publishes his *Historia Terrae et Maris*, in which he offers five stratigraphic distinctions for the mountains in the Harz area. He says that these strata reveal the history of Earth.

1762 Joseph Black (1729–1799), Scottish chemist, first introduces the term as well as the notion of "latent heat." He is the first to realize that there is a distinction between the quantity of heat and the intensity of heat.

1762 Marcus Anton von Plenciz, Sr. (1705–1786), Austrian physician, expresses the idea that all infectious diseases are caused by living organisms, and that there is a specific organism for each disease.

1763 Charles Mason (1730–1787) and Jeremiah Dixon (c.1733–1777), both English astronomers, are hired to begin their survey of the Pennsylvania-Maryland area in order to settle a dispute. This will take five years and will result in the Mason-Dixon Line, which becomes famous in U.S. history as the boundary between the free states and the slave states.

c.1763 Joseph Gottlieb Kolreuter (1733–1806), German botanist, publishes his pioneering work on plant hybridization and gives the first account of his experiments on artificial fertilization of plants. He also investigates pollination and the production of hybrid plants and recognizes the relationship between insects and cross-pollination.

1763 Nicolas Desmarest (1725–1815), French geologist, writes an article in the *Encyclopédie* in which he states that the dark, fine-grained basalt rock in France is volcanic in origin, as is much of the rock in that country. The idea that much of Europe was built on the remains of once-active volcanoes stirs a great controversy. Its proponents are called "Vulcanists," and they are opposed by such men as the German geologist Abraham Gottlob Werner (1750–1817), who leads the "Neptunist" school, which argues that all rocks are formed only by water.

1763 Rudolf Erich Raspe (1737–1794), German naturalist, publishes his *Specimen Historiae Naturalis Globi Terraquaei*, which is distinguished primarily for rediscovering the geological ideas of the English physicist Robert Hooke (1635–1703).

1764 Antoine Louis (1723–1792), French surgeon, introduces digital compression for hemorrhage.

1764 David Macbride (1726–1778), Irish surgeon, publishes his *Experimental Essays*, in which he tells of his discovery that van Helmont's "gas sylvestre" is similar to Black's recently-discovered "fixed air" (carbon dioxide). He also investigates carbon dioxide in human blood.

1764 Joseph Louis Lagrange (1736–1813), Italian-French astronomer and mathematician, publishes his *Vibration de la Lune*, in which he explains the periodic, side-to-side oscillations of the moon.

1765 First drawing of cell division is made by Abraham Trembley (1710–1784), Swiss naturalist, who witnesses multiplication of protozoans by division and cell division in algae.

1765 Giovanni Domenico Maraldi (1709–1788), Italian astronomer, observes and calculates the movements of Jupiter's satellites and offers a theory of their movement.

1765 James Watt (1736–1819), Scottish engineer, invents the separate condenser for the steam engine. By introducing a separate chamber to Thomas Newcomen's (1663–1729) steam engine, he produces a machine that ultimately is not only much more efficient in its use of fuel but also significantly quicker in the work it performs

1765 Karl Wilhelm Scheele (1742–1786), Swedish chemist, discovers prussic acid. Known also as hydrogen cyanide, this highly volatile, colorless liquid is extremely poisonous and is eventually used in industrial chemical processing.

1765 Lazzaro Spallanzani (1765–1777), Italian biologist, publishes his *Saggio di Osservazioni Microscopiche* and offers precise details of experiments as refutation of the theory of spontaneous generation of infusoria. He also succeeds in artificially inseminating a toad in 1780.

1765 Nevil Maskelyne (1732–1811), English astronomer, is appointed the fifth Astronomer Royal. During his career, he produces lunar tables and the *Nautical Almanac*, which remains a useful naviga-

tional aid for over a century. He also is the first to make time measurements that are accurate to a tenth of a second.

1765 The Bergakademie Freiberg is founded in Saxony. This illustrious German mining school becomes well-known for its faculty and famous alumni.

1765 The remains of mastodons are discovered by George Croghan in Kentucky.

1766 Horace Benedict de Saussure (1740–1799), Swiss physicist, invents the electrometer, the first device used to measure electronic potential.

1766 Jean Charles de Borda (1733–1799), French mathematician, publishes his *Memoire sur l'Ecoulement des Fluides par les Orifices*, in which he denies the possibility of solving all the problems of fluid mechanics using only known theories.

1766 Johann Carl Wilcke (1732–1796), Swedish physicist, makes the first chart containing information on magnetic inclination. He later conducts experiments and measures the latent heat of ice.

1766 Albrecht von Haller (1708–1777), Swiss physiologist, shows that feeling depends on nerves and that nerves activate muscles. He also traces nerves from the limbs to the cerebral cortex.

1766 Henry Cavendish (1731–1810), English chemist and physicist, publishes a paper, "On Factitious Airs," in the Royal Society's *Philosophical Transactions.* The paper relates his discovery of hydrogen or what he calls "inflammable air."

1766 Jean Darcet (1725–1801), French physician, publishes his *Mémoire sur l'Action d'Un Feu Egal, Violent, et Continue*, in which he shows that mixtures of minerals melt at lower temperatures than pure materials.

1766 Jean-Etienne Guettard (1715–1786), French geologist, and Antoine-Laurent Lavoisier (1743–1794), French chemist, begin an eleven-year project that becomes the first national geological survey. Although never completely finished, their maps contain stratigraphic information in columns placed in their margins.

1766 Johann Daniel Titius (1729–1796), German astronomer, suggests that there is a mathematical relationship existing in the distances between planets and the sun, and that there should be a planet between Mars and Jupiter. His idea becomes popularized by his countryman Johann Elert Bode (1747–1826).

1766 Pierre-Joseph Macquer (1718–1784), French chemist, publishes his *Dictionnaire de Chymie*, which is the first dictionary of chemistry.

1766 Torbern Olof Bergman (1735–1784), Swedish mineralogist, publishes his *Physisk Beskrifning ofver Jordklotet*, in which he classifies rocks by their geologic age.

1766 Gowan Knight (1713–1772), English natural philosopher, obtains the first English patent in the field of electricity and magnetism. It is for the construction of compasses "so as to prevent them from being affected by the motion of the ship."

1767 Joseph Priestley (1733–1804), English chemist, publishes his *History and Present State of Electricity, with Original Experiments*, in which he gives the study of pyroelectricity a prominent place.

1767 First astronomical ephemeris, *The British Nautical Almanac and Astronomical Ephemeris for the Meridian of the Royal Observatory at Greenwich*, is published and includes tables for the moon's positions at midnight and noon.

1767 William Hamilton (1730–1803), British Ambassador to the Court of Naples, begins a series of accounts of Vesuvius and Etna that he sends to the Royal Society, recording his observations and the sketches of the artist Pietro Fabri. These accounts are published in *Philosophical Transactions* from 1767 to 1795.

1768 Antoine Baume (1728–1804), French chemist, designs the aerometer. This is a major instrumentation advance since it has a scale with two fixed points (for liquid densities). This facilitates the production of properly calibrated instruments.

1768 Adam Kuhn (1741–1817), native of Germantown, Pennsylvania, and a student of

Carl Linnaeus, becomes the first professor of botany and *materia medica* in America at the College of Philadelphia.

1768 Antoine Baume (1728–1804), French chemist, introduces the aerometer, an instrument for determining the amount of alcohol in a hydroalcoholic mixture on the basis of density.

1768 Captain James Cook (1728–1779), English navigator, makes the first of his three famous voyages into the Pacific. The first of the really scientific navigators, he sails under the auspices of the Royal Society.

1768 Robert Whytt (1714–1766), Scottish physician, gives the first description of tuberculosis meningitis in children.

1768 William Heberden (1710–1801), English physician, first introduces the term "angina pectoris" to describe the painful heart condition caused by an oxygen deficiency.

1769 Alessandro Giuseppe Antonio Anastasio Volta (1745–1827), Italian physicist, publishes his *De Vi Attractiva Ignis Electrici ac Phaenomenis Indepentibus.* In what is his first work, Volta introduces the important electrical concept of potential.

1769 John Robison (1739–1805), Scottish physicist, determines experimentally that electrical attraction and repulsion follow an inverse-square law.

1769 Leonhard Euler (1707–1783), Swiss mathematician, publishes his *Dioptrics*, in which he demonstrates that refraction and dispersion in lenses are not proportional to each other. The significance of this is that it implies the possibility of building an achromatic objective (one concave and one convex lens, each made from a different type of glass).

1769 Fruits, walnuts, citrus, olives, figs, and pomegranates are introduced into California by mission fathers.

1769 Transit of Venus across the disc of the sun is observed and recorded from several locations. One of the observers is in Tahiti on English Captain James Cook's (1728–1799) vessel the *Endeavour.*

1770 Anders Johan Lexell (1740–1784), Swedish astronomer, works out the orbit of a comet he observes this year and determines its period of revolution to be five and a half years. This is the first short-term comet to have its orbit calculated.

1770 The first medical degree in the American colonies is conferred by Kings College.

1770 Johan Gottlieb Gahn (1745–1818) and Karl Wilhelm Scheele (1742–1786), both Swedish chemists, discover phosphorus (phosphoric acid) in bones, noting that it is an essential component.

1770 Joseph Priestley (1733–1804), English chemist, suggests the use of rubber to erase lead pencil marks. This introduces the name "rubber" in England.

1770 Karl Wilhelm Scheele (1742–1786), Swedish chemist, discovers tartaric acid. One of the most widely distributed of the plant acids, it eventually assumes a wide variety of food and industrial uses.

1770 A smallpox pandemic spreads over most of Europe.

1770 The Abbé Charles-Michel de l'Epée (1712–1780) invents sign language for deaf-mutes.

1770 William Hunter (1718–1783), English anatomist, founds a school of anatomy in London. It is here that the best British anatomists and surgeons of the period, including his brother John (1728–1793), are trained.

1771 Henry Cavendish (1731–1810), English chemist and physicist, publishes a paper titled "An Attempt to Explain Some of the Principal Phenomena of Electricity, by Means of an Elastic Fluid," in which he offers his general theory of electrical phenomena. Electrical fluid is matter, he states, although different from ordinary matter, and a body's natural state is saturation with electrical fluid, with saturation being an equilibrium between attractive and repulsive forces.

1771 John Hunter (1728–1793), English surgeon, founds scientific dentistry with his treatise *The Natural History of the Human Teeth.*

1771 Louis-Antoine de Bougainville (1729–1811), French navigator and explorer, pub-

lishes his *Voyage Autour du Monde*, in which he states that Earth has undergone major physical changes over a long period of time.

1771 Luigi Galvani (1737–1798), Italian anatomist, discovers the electric nature of nervous impulse.

1771 Peter Woulfe (c.1727–1803), English chemist, obtains picric acid by treating indigo with nitric acid. This substance dyes wool yellow and is considered to be the first artificial organic dye.

1772 Antoine-Laurent Lavoisier (1743–1794), French chemist, makes the first quantitative analysis of seawater.

1772 Daniel Rutherford (1749–1819), Scottish chemist, discovers nitrogen. It is also independently discovered shortly thereafter by Joseph Priestley (1733–1804), Karl Wilhelm Scheele (1742–1786), and Henry Cavendish (1731–1810).

1772 Jean-Baptiste-Louis Rome Delisle (1736–1790), French mineralogist, publishes his *Essai de Cristallographie*, in which he classifies minerals, stressing the importance of their geometry or external characteristics.

1772 Johann C. Lavater (1741–1801), Swiss physician, publishes his *Von der Physiognomik*, which transforms physiognomy into a logical study of the features of the human face.

1772 Johann Elert Bode (1747–1826), German astronomer, popularizes the ideas of Johann Daniel Titius concerning a mathematical formula for the relative distances between the sun and the planets. It becomes known as Bode's law and is not refuted until Neptune is discovered in 1846 in a position far from where it was predicted.

1772 Joseph Priestley (1733–1804), an English theologian and chemist, discovers that plants give off oxygen.

1772 Joseph Priestley (1733–1804), English chemist, experiments with "fixed air" and writes his "Directions for Impregnating Water with Fixed Air," in which he details how to make seltzer water using carbon dioxide and water. The distinctive taste of the seltzer or soda water gains Priestley much fame.

1772 Louis-Bernard Guyton de Morveau (1737–1816), French lawyer and chemist, demonstrates for the first time that metals gain weight on calcination (the chemical change that occurs when metals are heated to just below their fusion or melting point).

1773 Charles Augustin de Coulomb (1736–1806), French physicist, works on the mechanics of materials and presents the concepts of internal resisting moment and of shear deformation.

1773 First insane asylum in the American colonies is founded in Williamsburg, Virginia.

1773 John Walsh (1725–1795), English physicist, gives the first correct description of the torpedo fish and its electric organs. This cartilaginous fish has a flattened, disk-like body and a pair of electric organs near its head to shock its prey.

1773 Medical Society of London is founded.

1774 Abraham Gottlob Werner (1750–1817), German geologist, publishes his *Von den Ausselichen Kennzeichen der Fossilien*, which establishes a new language and new methods for classifying minerals. He devotes his career to the principle that all strata were laid down as sediment by the action of water and stridently resists the opposing school that argues for the action of heat and volcanoes.

1774 Alexander Wilson (1714–1786), Scottish astronomer, correctly deduces that sunspots are depressions or hollows. He uses a knowledge of the laws of perspective and some geometry to achieve this conclusion.

1774 Antoine-Laurent Lavoisier (1743–1794), a French chemist, discovers that oxygen is consumed during respiration.

1774 Domenico Cotugno (1736–1822), Italian anatomist, declares that cerebrospinal fluid, and not "animal spirit" as previously believed, fills the brain's cavities and ventricles.

1774 Felice Fontana (1730–1805), Italian chemist, invents the eudiometer, which is a finely graded and calibrated tube for the

volumetric measurement and analysis of gases.

1774 Joseph Priestley (1733–1804), English chemist, discovers oxygen or what he calls "dephlogisticated air." It had been isolated sometime between 1770 and 1773 by the Swedish chemist Karl Scheele (1742–1786) who calls it "fire air," but Priestley publishes his results first. It is named by Antoine-Laurent Lavoisier on September 5, 1779.

1774 Karl Wilhelm Scheele (1742–1786), Swedish chemist, discovers formic acid, a colorless, fuming liquid with a pungent odor. It is eventually used in processing textiles and leather.

1774 Manganese is discovered by the Swedish mineralogist Johann Gottlieb Gahn (1745–1818) and Swedish chemist Karl Wilhelm Scheele (1742–1786).

1774 Nevil Maskelyne (1732–1811), English astronomer, conducts an experiment using a plumb line to determine the density of Earth. He finds that its density is 4.5 times that of water.

1774 Thomas Percival (1740–1804), English physician, is the first English physician to recommend cod liver oil as a remedy for tuberculosis.

1774 Caroline Lucretia Herschel (1750–1848) builds with her brother, German-English astronomer William Herschel (1738–1822), the best reflector telescope to this time. Together, they grind the best lenses in Europe and use them to search the skies. Caroline later discovers eight comets by herself and becomes the first female astronomer of note.

1775 Antoine-Laurent Lavoisier (1743–1794), French chemist, publishes his "Mémoire" paper, which contains his first major disavowal of the phlogiston theory as well as a revision of his combustion theory.

1775 First American textbook on surgery is *Plain, Concise, Practical Remarks on the Treatment of Wounds and Fractures* by John Jones (1729–1791). He writes it to assist the military surgeons who attend the American soldiers.

1775 Friedrich Gottlieb Glaser (1749–1804) of Germany publishes his *Versuch einer Mineralogischen Beschreibung der Gefurstetn Graffschaft Henneberg*, which contains the first colored geologic map.

1775 Torbern Olaf Bergman (1735–1784), Swedish mineralogist, publishes a new table of affinities (the attraction of one substance for another).

1775 The Continental Congress establishes a medical service to assist an army of 20,000 soldiers. They create a Hospital Department and name Dr. Benjamin Church of Boston, Massachusetts, as Director General and Chief Physician.

1776 Jean Charles de Borda (1733–1799), French mathematician, is the first to establish accurately a knowledge of a third element of terrestrial magnetism, i.e., its intensity.

1776 Alessandro Volta (1745–1827), Italian physicist, discovers marsh gas (methane), which is inflammable, in the reed-beds of Lake Maggiore.

1776 Johann F. Blumenbach (1752–1840) of Germany founds scientific anthropology. His book, *De Generis Humani Varietate Nativa*, is considered the starting point of modern ethnology, because it classifies the human races according to skull shape and skin color.

1776 Matthew Dobson (1732–1784), English physician, publishes his paper "Experiments and Observations on the Urine in Diabetes," and first proves that the sweetness is caused by sugar, which is present in the urine and in the blood (hyperglycemia).

1776 Publication begins of the *Berliner Jahrbuch*, which contains accurate annual ephemerides and astronomical news.

1776 Torbern Olof Bergman (1735–1784), Swedish mineralogist, and his student Karl Wilhelm Scheele (1742–1786), Swedish chemist, discover uric acid in vesical calculi.

1776 William Cumberland Cruikshank (1745–1800), Scottish surgeon and chemist, discovers that severed nerves can grow back together.

1776 William Hamilton (1730–1803), British Ambassador to the Court of Naples, privately publishes *Campi Phlegraei.* Containing his observations and Pietro Fabri's drawings of the volcanoes at Etna and Stromboli, this book becomes one of the handsomest geology books ever published.

1777 Tiberius Cavallo (1749–1809), Italian physicist, publishes his *Complete Treatise on Electricity*, in which he describes his many electrical experiments and the various instruments he invented.

1777 American General George Washington (1732–1799) orders the inoculation of the Continental Army to prevent smallpox.

1777 Carl Wenzel (1740–1793), German chemist, discovers the reaction rates of various chemicals, concluding that they are roughly proportional to the substance concentration.

1777 The first journal in botany, *Botanical Magazine*, begins publication.

1777 Karl Wilhelm Scheele (1742–1786), Swedish chemist, publishes his *Chemische Abhandlung von der Luft und dem Feuer*, in which he describes his earlier experiments on "fire air" or oxygen.

1777 Pierre Simon Pallas (1741–1811) of Prussia publishes the first of his scientific findings from his Siberian explorations (1768–1774). This expedition was commissioned by Russian Empress Catherine II (1729–1796), paid for by the Russian government, and organized by the St. Petersburg Academy of Sciences.

1778 Giuseppe Toaldo (1719–1798), Italian meteorologist, first introduces the lightning rod in the Venetian States.

1778 Barthélemy Faujas de Saint-Fond (1741–1819), French geologist, publishes his *Recherches sur les Volcans Eteints du Vivarais et du Velay*, which becomes an important contribution to the literature of volcanic geology. His book contains lavish drawings that demonstrate convincingly the connection between the columnar rock formations and volcanic cones.

1778 First pharmacopeia in the United States is published by Dr. William Brown of Virginia. Published in Philadelphia, it is intended to be used by the Continental Army.

1778 Hubert Franz Hofer of Germany discovers boric acid exists naturally in a hot spring in Tuscany, Italy.

1778 John Whitehurst (1713–1788), English clockmaker, publishes *An Inquiry into the Original State and Formation of the Earth*, which is significant for his accurate description of the regular sequence of the strata in the Derbyshire, England, mining region. Although he has never seen a volcano, he recognizes, via William Hamilton's descriptions and drawings, that the Derby formations are volcanic in origin.

1778 Tobern Olaf Bergman (1735–1784), Swedish mineralogist, offers the first comprehensive analysis of mineral water.

1779 *Pyrometrie; oder, Vom Maase des Feuers und der Warme* by the German mathematician Johann Heinrich Lambert (1728–1777) is published posthumously. It studies the expansion of air and problems related to heat radiation and forms the basis of much thermological research to come.

1779 Franz Anton Mesmer (1734–1815), German physician, publishes his *Memoire sur la Decouverte du Magnetisme Animal.* Having begun using magnets to cure disease, he then progresses to a sort of laying-on of hands he calls "animal magnetism." His doctrines have some truth to them as they are based on the power of suggestion and the reality of psychosomatic illnesses, but he is eventually discredited and forced to leave Paris.

1779 Pierre Louis Georges Du Buat (1734–1809), French engineer, publishes his *Principes d'Hydraulique*, in which he discusses the problems related to the resistance of fluids to the passage of solid bodies.

1779 Horace-Bénédict de Saussure (1740–1799), Swiss physicist, publishes his *Voyages dans les Alpes*, in which he is the first to use the word "geology." As the first person to climb mountains in order to investigate them scientifically, he writes four volumes

of accurate observations on mountains and glaciers.

1779 Antoine-Laurent Lavoisier (1743–1794), French chemist, first proposes the name "oxygen" for that part of the air that is breathable and is responsible for combustion.

1779 Jan Ingenhousz (1730–1799), Dutch physician and plant physiologist, publishes his *Experiments upon Vegetables* in London and shows that light is necessary for plants to produce oxygen and that sunlight is the energy source for photosynthesis. He also says that carbon dioxide is taken in by plants in the daytime and given off at night.

1779 Johann F. Blumenbach (1752–1840) of Germany publishes his influential textbook on natural history, *Handbuch der Naturgeschichte.*

1779 Lazzaro Spallanzani (1729–1799), Italian biologist, shows that seminal fluid is necessary to fertilization.

1779 Paolo Mascagni (1752–1815), Italian anatomist, discovers solid boric acid (sassolit) in Montecerboli and Castelnuovo in his native land.

1780 Charles Augustin Coulomb (1736–1806), French physicist, publishes the first of two papers that establish his theory of torsion in thin threads and discuss his invention of the torsion balance. This sensitive instrument can measure the quantity of a force, and he later uses it to conduct electrical experiments.

1780 Samuel Williams, American professor in Massachusetts, makes the earliest known observations of the magnetic dip in the United States.

1780 The American Academy of Arts and Sciences is founded in Boston, Massachusetts.

1780 Antoine-Laurent Lavoisier (1743–1794), French chemist, and Pierre-Simon Laplace (1749–1827), French astronomer and mathematician, collaborate to demonstrate that respiration is a form of combustion. Breathing, like combustion, liberates heat, carbon dioxide, and water.

c.1780 Claude-Louis Berthollet (1748–1822), French chemist, establishes the composition of ammonia and conducts the first thorough study of chlorine, introducing it as a bleaching agent.

1780 Fire or pear blight is first noted in New York by William Denning.

1780 George Adams (1750–1795), English engineer, devises the first microtome. This mechanical instrument cuts thin slices for examination under a microscope and replaces the imperfect sample cutting by a hand-held razor.

1780 Jean-Louis Giraud Soulavie (1752–1813), French cleric, publishes the first of eight volumes titled *Histoire Naturelle de la France Méridionale.* In this work, his stratigraphic maps begin to show the relative time relationships by the fossils found there, thus pointing the way for others to follow.

1780 Karl Wilhelm Scheele (1742–1786), Swedish chemist, discovers lactic acid. Found in the soil, in the blood and muscles of animals, and in fermented milk products, it eventually is used in food processing and for tanning leather and dyeing wool.

c.1780 Last wolf on the British Isles is killed.

1781 Antoine-Laurent Lavoisier (1743–1794), French chemist, demonstrates that electricity is developed when solid or fluid bodies pass into a gaseous state.

1781 Johan Carl Wilcke (1732–1796), Swedish physicist, introduces the concept of specific heat (the ratio of the quantity of heat required to raise the temperature of a body one degree to that required to raise the temperature of an equal mass of water one degree).

1781 Charles Messier (1730–1817), French astronomer and comet hunter, publishes a list of nebulosities or fuzzy objects in the sky that others might mistake for comets. The objects in his list are still frequently known as Messier 1, Messier 2, and so on. Although Messier was an excellent hunter of comets, he becomes best known for his miscellany list of over a hundred spurious objects.

1781 Déodat de Gratet de Dolomieu (1750–1801), French geologist, publishes his

Voyage aux Isles de Lipari, in which he notes that the extreme heat of volcanic magma cannot be accounted for by combustion alone, but which he is also unable to explain.

1781 Massachusetts Medical Society is founded.

1781 Peter Jacob Hjelm (1746–1813), Swedish chemist, discovers molybdenum, a tough, malleable silver-white metal used as an alloy. He reduces molybdic acid to a metal state using carbon as a reducing agent.

1781 William Herschel (1738–1822), German-English astronomer, discovers the planet Uranus, the first new planet to be discovered in historic times.

1782 Edward Nairne (1726–1806), English physicist, builds a cylinder electrical machine that is the most powerful to date and also constructs the largest battery known to this time.

1782 Georges Louis Lesage (1724–1803), Swiss physicist and mathematician, publishes his *Newtonian Lucretius*, in which he attempts to explain a mechanist theory of gravitation.

1782 Torbern Olaf Bergman (1735–1784), Swedish mineralogist, publishes his *Sciagraphia Regni Mineralis*, in which he classifies minerals into four main groups: salts, earths, metals, and inflammable bodies.

1782 Antoine-Laurent Lavoisier (1743–1794), French chemist, studies metals that have calcinated or rusted and observes that their total weight is not changed but merely shifted around. This establishes an early version of the first law of conservation of matter.

1782 Franz Müller (1740–1825), Austrian mineralogist, discovers tellurium.

1782 James Watt (1736–1819), Scottish engineer, patents the double-acting steam engine, in which the piston both pushes and pulls.

1782 John Goodricke (1764–1786), Dutch-English astronomer, is the first to show that the noticeable variations in the brightness of the star Alogol have a regularity. He also makes the bold but correct suggestion that the light change is caused by an invisible companion star that periodically eclipses Algol. His accomplishments are remarkable given that he not only died in his twenty-second year, but that he was a deaf mute from birth.

1783 Antoine-Laurent Lavoisier (1743–1794), French chemist, and Pierre-Simon Laplace (1749–1827), French astronomer and mathematician, co-author *Memoire sur la Chaleur*. They demonstrate that the quantity of heat required to decompose a compound into its elements is equal to the heat evolved when that compound was formed from its elements. Based on a large amount of experimental data on specific heat, this work helps to lay the foundation of thermochemistry. It also leads Lavoisier to conclude that respiration is a form of combustion.

1783 Horace Benedict de Saussure (1740–1799), Swiss physicist, publishes his *Essais sur L'Hygrometrie*, in which he details his invention of a hygrometer that uses human hair for measuring humidity. He also discusses the general principles of hygrometry.

1783 Lazare Nicolas Marguerite Carnot (1753–1823), French military engineer and mathematician, publishes his *Essai sur Les Machines en General*, which is a systematic exposition of mechanics and the concept of force. Carnot offers the earliest demonstration that kinetic energy is lost in the collision of bodies.

1783 A volcanic eruption in Iceland that kills one-fifth of that island's population leads American statesman and scientist Benjamin Franklin (1706–1790) to suggest that such a major eruption could cause a decrease in temperature if the dust screened out the sun's rays.

1783 Alexandre-Gui Pingré (1711–1796), French astronomer, publishes his two-volume *Cometographie*; its thoroughness makes it a major source on all aspects of cometary information.

1783 Antoine-Laurent Lavoisier (1743–1794), French chemist, repeats the experiment of Henry Cavendish and realizes that he is

dealing with a separate, new gas. He calls this inflammable gas "hydrogen," from the Greek words meaning "to give rise to water."

1783 Chinch bug is first noted as a pest of wheat in the United States in North Carolina.

1783 The first medical journal printed in America is a translation of the French *Journal de Médecine Militaire.* It ceases publication in 1790.

1783 Juan Jose D'Elhuyar (1754–1796) and his younger brother, Don Fausto D'Elhuyar (1755–1833), both Spanish mineralogists, analyze a mineral called wolfram and discover the new metal tungsten.

1783 Karl Wilhelm Scheele (1742–1786), Swedish chemist, discovers glycerin. Also called glycerol, it is a thick, clear, sweet-tasting liquid that comes to be used in making resins and gums for paints and as a softener in other products.

1783 Nicolas Leblanc (1742–1806), French chemist, invents a process for the manufacture of soda (sodium hydroxide and sodium carbonate) from salt (sodium chloride). He soon opens a factory to manufacture soda that is much-needed in France for a variety of chemical purposes. This is the first chemical discovery that has an immediate commercial use. It is also the first major example of a technology being born out of an advance in theoretical science.

1783 William Herschel (1738–1822), German-English astronomer, discovers that the sun and the rest of the solar system are moving through space relative to other stars. He states it is moving toward a point in the constellation of Hercules.

1784 George Atwood (1745–1807), English physicist and mathematician, accurately calculates the acceleration of a body in free-fall.

1784 Henry Cavendish (1731–1810), English chemist, establishes that water is formed when "inflammable air" or hydrogen is burned in ordinary air or "dephlogisticated air" (oxygen). He publishes his findings on the synthesis of water from two gases in *Philosophical Transactions.*

1784 Johann Wolfgang von Goethe (1749–1832), German poet, discovers the intermaxillary bone.

1784 John Michell (1724–1793), English geologist and astronomer, reasons that if light is a particle (as Newton suggests), then the force of gravity from a sufficiently large body could prevent light from moving outward. This originates the concept of the black hole. He also makes the first realistic estimate of the distance between Earth and a star.

1784 Karl Wilhelm Scheele (1742–1786), Swedish chemist, discovers citric acid, commonly found in nearly all plants and in many animal tissues and fluids. It comes to be used mainly as a flavoring agent in drinks.

1784 René Just Haüy (1743–1822), French mineralogist, publishes his *Essai d'une Théorie sur la Structure des Crystaux.* Haüy joins mathematics and mineralogy and lays the foundation of the mathematical theory of crystal structure. He offers his law of crystal symmetry, which states that crystals are the result of the stacking-together of tiny, identical units.

1784 Richard Kirwan (1733–1812), Irish geologist, publishes his *Elements of Mineralogy,* in which he introduces the use of chemical composition as a means of classifying minerals.

1784 David Landreth opens the first seed business in the United States in Philadelphia, Pennsylvania.

1785 Charles Augustin Coulomb (1736–1806), French physicist, publishes the first of seven papers in which he establishes the basic laws of electrostatics and magnetism. Using his newly-invented torsion balance, he determines that Newton's law of inverse squares also applies to electrical and magnetic attraction and repulsion. He states that the degree of attraction or repulsion depends on the amount of the electric charge or the magnetic pole strength.

1785 Humphry Marshall (1722–1801), American botanist, publishes his *Arbustum Americanum: The American Grove,* the

first American book devoted expressly to botany. It is published in Philadelphia, Pennsylvania.

1785 John Hunter (1728–1793), English surgeon, discovers collateral circulation and introduces proximal ligation (tying off a blood vessel) in the case of aneurysm. Hunter is a founder of experimental and surgical pathology as well as a pioneer in comparative physiology and experimental morphology.

1785 Martinus Van Marum (1750–1837), Dutch botanist and physicist, obtains ozone by striking an electric spark in oxygen. He describes a very strong odor as "clearly the smell of electric matter," but does not recognize his discovery.

1785 Pierre-Simon Laplace (1749–1827), French astronomer and mathematician, states that the rings of Saturn are neither one nor two solid rings but consist of many solid ringlets.

1785 Thomas Fowler (1736–1801), English physician, introduces potassium arsenate or "Fowler's solution" as a therapeutic drug in liquid form.

1785 William Herschel (1738–1822), German-English astronomer, publishes *On the Construction of the Heavens*, in which he offers his conclusions about the shape of the universe. He views the visible universe as representing a gigantic collection of stars arranged roughly in the shape of a grindstone with our own sun somewhere near the center. This is the first systematic attempt to determine the shape of the Milky Way galaxy.

1785 William Withering (1741–1799), English physician, uses digitalis as a cure for dropsy (abnormal increase of fluid).

1785 James Hutton (1726–1797), Scottish geologist, reads his first paper, "Concerning the System of the Earth," to the Royal Society of Edinburgh. It is out of this brief paper that geology has its beginnings as a real science or as an organized field of study. Hutton offers a theory called "uniformitarianism," which contains one of the most fundamental principles of geology—that natural processes have been constantly at work shaping the earth over enormously long periods of time. The prime force behind this shaping is the internal heat of the Earth. These ideas meet considerable resistance, but Hutton eventually prevails and comes to be known as the "father of geology."

1786 Claude-Louis Berthollet (1748–1822), French chemist, and French mathematicians Gaspard Monge (1746–1818) and Alexandre-Theophile Vandermonde (1735–1796), publish a paper, "Mémoire sur le Fer," which first establishes that the difference between iron and steel is due to carbon.

1786 Jean-Baptiste Delambre (1749–1822), French astronomer, produces new tables of the planetary motions of Jupiter and its satellites, Saturn, and the newly discovered planet Uranus. He also spends six years measuring the full north-south distance of France before that country formally adopts the metric system.

1786 Mont Blanc, in southeast France on the Italian border and the highest of the Alps, is first climbed by Jacques Balmat (1762–1834) and Michel-Gabriel Paccard (1757–1827). The notion of mountains as inaccessible, accursed places is beginning to change, and they are becoming fit subjects for scientific investigation.

1787 Abraham Bennet (1750–1799), English physicist and inventor, is the first to observe the contact electrification of metals. He also invents the gold-leaf electroscope.

1787 Ernst Florens Friedrich Chladni (1756–1827), German physicist, publishes his *Theorie des Klanges*, in which he is the first to discover the quantitative relationships that rule the transmission of sound. He also creates "Chladni's figures" by spreading sand on thin plates and vibrating them, producing complex patterns from which much is learned about vibrations. He is considered the father of acoustics.

1787 Jacques Alexandre Charles (1746–1823), French physicist, repeats the gas-expansion work of his countryman Guillaume

Amontons (1663–1705) and is the first to offer the rule that the volume of a given quantity of gas is proportional to the absolute temperature if the pressure is held constant.

1787 René Just Haüy (1743–1822), French mineralogist, publishes his paper "Exposition raisonnee de la Theorie de l'Electricite et du Magnetisme," in which he makes important contributions to the study of pyroelectricity. He also makes the most extensive and accurate observations on the development of electricity in minerals by friction.

1787 Abraham Gottlob Werner (1750–1817), German geologist, publishes his *Kurze Klassifikation*, in which he states his theory that basalt rock is aqueous (Neptunism) and not volcanic in origin (Vulcanism). This is the first systematic treatise on geologic formations.

1787 Antoine-Laurent Lavoisier (1743–1794), French chemist, publishes *Methode de Nomenclature Chimique* in collaboration with French chemist Louis-Bernard Guyton de Morveau (1737–1816). This book gives the new chemistry a modern terminology and changes chemical nomenclature to correspond to the new antiphlogiston theory.

1787 First separate book on horticulture in North America is written by Robert Squibb. His book, *The Gardener's Calendar for South Carolina and North Carolina*, is published in Charleston, South Carolina.

1787 Jacques-Alexandre Charles (1746–1823), French physicist, demonstrates that different gases all expand by the same amount with a given rise in temperature. This becomes known as "Charles law" (and also "Gay-Lussac's law" after Joseph Louis Gay-Lussac, who published work based on Charles's in 1802).

1787 Johann David Schopf (1752–1800), German-American geologist, publishes his *Beitrage zur Mineralogischen Kentniss der Ostlichen Theils von Nordamerika*, which is the first book on American geology.

1787 Pierre-Simon Laplace (1749–1827), French astronomer and mathematician, shows that the moon is accelerating slightly more than could be explained. He attributes this to Earth's changing orbit, which itself is the result of the gravity of other planets.

1788 Joseph Louis Lagrange (1736–1813), Italian-French astronomer and mathematician, publishes his *Mecanique Analytique*, which is a systematization of mechanics. In it he summarizes all the work done in the field of mechanics since the time of Newton. He uses a rigorous mathematical treatment to unify mechanics. He also works out mathematical treatments of the motions of systems containing two or more bodies, such as the Earth-moon-sun system and the system of Jupiter and its four moons.

1788 Charles Blagden (1748–1820), English physician and secretary of the Royal Society, discovers that the lowering of the freezing point of a solution is proportional to the concentration of the solute. This becomes known as "Blagden's law."

1788 James Hutton (1726–1797), Scottish geologist, publishes his "Theory of the Earth" in the inaugural volume of *Transactions of the Royal Society of Edinburgh.* By this time, Hutton's 1785 paper containing his theory of "uniformitarianism" has reached 100 pages.

1788 The Act for the Better Regulation of Chimney Sweepers and their Apprentices of this year is passed in England. This piece of legislation seeks to protect the poor, young "climbing boys" employed as sweeps, among whom the incidence of scrotal cancer is very high.

1789 Antoine de Jussieu (1748–1836), French botanist, publishes his *Genera Plantarum*, a widely accepted book that incorporates the Linnean system of binomial nomenclature and is considered to be the foundation of the natural system of botanical classification.

1789 Antoine-Laurent Lavoisier (1743–1794), French chemist, publishes *Traité Elémentaire de Chimie*, which defines the new science of chemistry and becomes the first modern chemical textbook. In it, he uni-

fies the subject and states his law of the indestructibility of matter (conservation of mass). He also popularizes chemistry and puts an end to the old phlogiston theories.

1789 Armand Seguin (1765–1835) and Antoine-Laurent Lavoisier (1743–1794), French chemists, make the first measurements of the human metabolism rate. Lavoisier uses his young assistant, Seguin, as the experiment subject.

1789 Edward Wigglesworth, Divinity Professor at Harvard University, constructs the first American life-table.

1789 First French journal for chemistry, *Annales de Chimie*, is founded by French chemist Antoine-Laurent Lavoisier (1743–1794) and his colleagues.

1789 Martin Heinrich Klaproth (1743–1817), German chemist, discovers uranium and zirconium in pitchblende. This is the same substance that Pierre and Marie Curie will refine in 1898.

1789 William Higgins (c.1762–1825), Irish chemist, publishes his *Comparative View of the Phlogistic and Anti-Phlogistic Theories*, in which he anticipates both John Dalton's (1766–1844) atomic theory and the chemical symbolism of Jöns Jakob Berzelius (1779–1848). His work is little known in his lifetime.

1789 William Herschel (1738–1822), German-English astronomer, builds a telescope with a focal length of 40 feet (12.2 m) and with a 48-inch (1.22 m) reflector or mirror. On the first night he uses it, he discovers two new satellites of Saturn.

1790 Antonio Maria Vassalli-Eandi (1761–1825), Italian physicist, publishes a report of his experiments concerning electricity and water and ice.

1790 Friedrich Albrecht Carl Gren (1760–1798), German chemist and physicist, founds the *Journal der Physik* as a periodical for the "mathematical and chemical branches of natural science." It is succeeded by the *Neues Journal der Physik*.

1790 Johann Georg Tralles (1763–1822), German-Swiss physicist, is the first to report on the negative electricity of waterfalls.

1790 Adair Crawford (1748–1795), Irish physician and chemist, and William Cumberland Cruikshank (1745–1800), Scottish surgeon and chemist, discover strontium.

1790 First U.S. census is conducted.

1790 James Derham (1762–?) becomes the first African-American to practice medicine in the United States.

1791 James Keir (1735–1820), English chemist, contributes to the discovery of the electroplate process with his experiments immersing metals in different solutions.

1791 Johann Wolfgang von Goethe (1749–1832), German poet, publishes the first of two volumes of his *Beytrage zur Optik*, in which he opposes the views of English scientist and mathematician Isaac Newton (1642–1727) on the formation of colors out of white light.

1791 Luigi Galvani (1737–1798), Italian anatomist, publishes his *De Viribus Electricitatis in Motu Musculari*, in which he investigates what he calls "animal electricity." During his dissections of frogs, Galvani notes that their legs twitch when touched with a scalpel. He actually discovers a phenomenon of enormous potential—that an electric current can be produced from the contact of two different metals in a moist environment—but he misinterprets its larger meaning and concludes that the electricity is within the animal itself. Although he is partly correct, since bioelectric forces do exist within animal tissue, he overgeneralizes and fails to see the important role of metals. His countryman, Alessandro Volta (1745–1827), does not make the same mistake.

1791 Pierre Prevost (1751–1839), Swiss physicist, offers his theory of exchanges. He correctly states that all bodies of all temperatures radiate heat, noting that the cold does not flow from the snow to the hand, but rather it is the loss of heat and not the gain of cold that makes the hand feel cold. This is an important and fertile distinction to the later science of thermodynamics.

1791 First significant American-born naturalist, William Bartram (1739–1823), publishes

his *Travels through North & South Carolina, Georgia, East & West Florida.* Filled with generalized botanical, zoological, and anthropological descriptions, it is the product of a man some call the first American ecologist.

1791 Pieter Camper (1722–1789), Dutch physician and artist, produces one of the earliest works on physical anthropology. His posthumously-published *Sur Les Différences que Présente Le Visage dans Les Races Humaines* establishes the bases for craniometric measurements.

1791 Thomas Young (1773–1829), English physicist and physician, begins his studies on physiological optics, during which he discovers the cause of astigmatism.

1791 William Gregor (1761–1817), English mineralogist, discovers titanium.

1791 The French National Assembly adopts the metric system based on decimals as the unit of measure for length and adopts the meter as the "natural" unit of length, since it will be figured from the actual distance between two points on Earth. It takes until 1810 to accurately establish the distance between Barcelona, Spain, and Dunkerque, France.

1792 Eusebio Valli (1755–1816), Italian physician, publishes his paper "Experiments on Animal Electricity," in which he shows that of all metals applied to an animal's nerves, zinc creates the most powerful contractions.

1792 Jeremias Benjamin Richter (1762–1807), German chemist, founds stoichiometry with the publication of his book *Anfangsgtunde der Stochymetrie.* His law of equivalent proportions or laws of equivalents form the basis of this form of quantitative chemistry, which states that substances react with each other in fixed proportions.

1792 Lazzaro Spallanzani (1729–1799), Italian naturalist and biologist, publishes the first of his six-volume work, *Viaggi alle due Sicilie e in Alcune Parti dell'Appenine*, in which he is the first to study volcanic rock experimentally.

1792 Pierre-Joseph Desault (1744–1795), French surgeon, describes his successful surgical removal of part of the thyroid.

1793 John Dalton (1766–1844), English chemist, publishes the results of his experiments on electricity in the atmosphere. He shows that the aurora borealis makes a magnetic needle move irregularly.

1793 Christian Konrad Sprengel (1750–1816), German botanist, clearly describes the role of insects in plant fertilization in his *Das Entdeckte Geheimniss der Natur im Bau und in der Befruchtung der Blumen*, published in Berlin.

1793 Philippe Pinel (1745–1826), French physician, pioneers the humane treatment of the mentally ill.

1793 Thomas Young (1773–1829), English physicist and physician, describes the mechanism of accommodation in the eye, in which it adjusts automatically at different distances. He says this is accomplished by the curvature of the lens.

1794 Erasmus Darwin (1731–1802), English physician and grandfather of Charles Darwin and Francis Galton, publishes his *Zoonomia*, in which he elaborates on Buffon's evolutionary ideas and stresses the role of the environment in changes in organisms. Darwin argues that evolutionary changes are brought about by the mechanism primarily associated with Jean Baptiste Lamarck, that is, the direct influence of the environment on the organism.

1794 Ernst Florens Friedrich Chladni (1756–1827), German physicist, is one of the first scientists to write that meteors fall to Earth from the heavens. While most peasants believe this, few scientists of this time agree. Chladni argues that they are the debris of exploded planets.

1794 The first paper on systematic zoology published in America is written by American naturalist William Dandridge Peck (1763–1822). It is titled "Descriptions of Four Remarkable Fishes Taken Near the Pisquataqua in New Hampshire."

1794 First successful Caesarean section in the United States is performed by Jesse Bennett (1769–1842) of Virginia on his wife.

1794 Johan Gadolin (1760–1852), Finnish chemist, discovers a new mineral at a quarry called Ytterby in Sweden. The mineral is called yttrium and is later found to contain over a dozen different elements which come to be called "rare earth" elements.

1794 John Dalton (1766–1844), English chemist, first describes color-blindness. Dalton himself is color-blind.

1795 Martin Heinrich Klaproth (1743–1817), German chemist, isolates the new metal titanium and names it after the Titans of Greek mythology. He also gives full credit to English mineralogist William Gregor (1761–1817), who first discovered it in 1791.

1796 Pierre Simon Laplace (1749–1827), French astronomer and mathematician, publishes his *Exposition du Systéme du Monde*, in which he generalizes Newtonian mechanics. To Laplace, the natural laws are in perfect agreement with all phenomena. It also contains his famous "nebular hypothesis" in a note at the end of the book. He states that a gaseous universe condensed and contracted, and the planets formed as its particles collected at the center. He speculates that the sun originated as a giant cloud of gas or nebula that was in rotation, and that by centrifugal force the core of the nebula became the sun and the rim of gas became the planets. A similar idea had been advanced by Immanuel Kant forty-one years earlier.

1796 Georges Cuvier (1769–1832), French anatomist, is the first to extend the system of classification to fossils. He notes that although many fossils are different from living animals, they nonetheless belong to one of the four phyla he had established.

1796 Jan Ingenhousz (1730–1799), Dutch physician and plant physiologist, concludes that plants utilize carbon dioxide. He finds that the activities of plants and animals complement each other, with plants taking in people's carbon dioxide and giving them oxygen in return.

1796 John Abernathy (1764–1831), English surgeon, is the first to ligate the external iliac artery in a case of aneurysm.

1796 Smithson Tennant (1761–1815), English chemist, conducts a series of quantitative combustion experiments and establishes for the first time that a diamond is chemically identical with carbon.

1796 Edward Jenner (1749–1823) uses cowpox virus to develop a smallpox vaccine. He inoculates James Phipps with cowpox to protect him from smallpox. With this successful demonstration of vaccination, Jenner proves that inoculation can create immunity.

1797 Giovanni Battista Venturi (1746–1822), Italian physicist, conducts research on lateral movement of fluids and discovers that when water passes through a constricted space its velocity increases, and its pressure falls.

1797 The *Journal of Natural Philosophy, Chemistry and the Arts* is founded by English physicist William Nicholson (1753–1815) in London.

1797 The first original medical journal published in the United States is the *Medical Repository*, a quarterly edited in New York. For seven years, it is the country's only medical journal.

1797 Georges Cuvier (1769–1832), French anatomist, founds comparative zoology. With the publication of his first book, *Tableau Elémentaire de l'Histoire Naturelle des Animaux*, Cuvier introduces his basic ideas and principles on how the functions and habits of animal determine form (and not the reverse).

1797 Heinrich Wilhelm Matthaus Olbers (1758–1840), German astronomer, works out a simplified method for determining the orbits of comets that is still used today.

1797 Oliver Evans (1755–1819), American inventor, receives a U.S. patent for a steam engine.

1797 The solitaire, a large flightless bird of Rodriguez Island in the Indian Ocean, becomes extinct.

1797 William Hyde Wollaston (1766–1828), English physician and chemist, discovers uric acid in gouty joints.

1798 Benjamin Thompson, Count Rumford (1753–1814), American-British physicist, bores a cannon with a blunt drill and generates an unlimited amount of heat; this makes him question the prevailing "caloric" notion that heat is a fluid or liquid form of matter. He eventually overturns this theory and establishes the beginnings of the modern theory that heat is a form of motion.

1798 Henry Cavendish (1731–1810), English chemist and physicist, makes the first accurate determination of Earth's mean density, and therefore first measures its mass. He does this by obtaining what Isaac Newton had not provided—a value for the gravitational constant. He builds a model with light balls and large, heavy ones and uses a sensitive wire to calculate the strength of the attraction between the two. Using a torsion balance to which he attaches a suspended beam with two lead balls, he measures the period of oscillation and arrives at a mean density figure of 5.48 times that of water. Once he obtains this constant value, he calculates Earth's mass at nearly what we know it to be today.

1798 Caroline Lucretia Herschel (1750–1848), German-English astronomer, publishes her *Index to Flamsteed's Observations of the Fixed Stars*, in which she revises Flamsteed's star catalog and indexes every star it includes.

1798 James Hall (1761–1832), Scottish geologist and chemist, begins a series of papers between this year and 1812 in which he provides experimental evidence for Hutton's geological theories. Because of his ability to back Hutton's views by facts obtained experimentally, he is considered the founder of experimental geology and of geochemistry.

1798 Louis-Bernard Guyton de Morveau (1737–1816), French chemist, liquefies ammonia by using a mixture of ice and calcium chloride to cool the gas to −44° C (−47.2° F).

1798 Louis-Nicolas Vauquelin (1763–1829), French chemist, discovers the element chromium and prepares several of its compounds. He discovers beryllium this same year.

1798 Pierre-Simon Laplace (1749–1827), French astronomer and mathematician, publishes the first of his monumental five-volume work *Traité de Mécanique Céleste*. The entire work takes twenty-seven years to complete and brilliantly codifies and develops the work of his predecessors. It also contains many abstract theories that are confirmed by later mathematicians. Laplace becomes known as the "Newton of France."

1798 Government legislation is passed to establish hospitals in the United States devoted to the care of ill mariners. This initiative leads to the establishment of a Hygienic Laboratory that eventually grows to become the National Institutes of Health.

1798 Benjamin Henry Latrobe (1764–1820), American architect and engineer, writes in his journal that rocks weather into soil and that river erosion can carve out valleys.

1799 Giovanni Valentino Mattia Fabbroni (1752–1822), Italian chemist, makes the first known suggestion of the chemical origins of Luigi Galvani's electrical discoveries. He does not propose an alternative theory to galvanism however.

1799 Alexander von Humboldt (1769–1859), German naturalist, begins his scientific explorations in South America (1799–1804).

1799 Antoine-François de Fourcroy (1775–1809), French physician and chemist, isolates urea.

1799 John Dalton (1766–1844), English chemist, writes that rain and dew compensate for water that is carried away by rivers and evaporation. His first love is meteorology, and Dalton keeps careful daily records for fifty-seven years.

1799 Joseph-Louis Proust (1754–1826), French chemist, demonstrates that all compounds contain elements in certain, definite proportions. This come to be known as "Proust's law."

1799 Smithson Tennant (1761–1815), English chemist, begins to manufacture bleaching powder in Scotland.

1799 Tuberculosis probably reaches its greatest height as a cause of death in Europe. It is estimated to cause 1 out of 3.8 deaths.

1799 William Smith (1769–1839), English geologist, creates a geologic map based on scientific principles that he discovers. After years of exploring his native England as a surveyor, Smith realizes that each stratum has its own characteristic form of fossils, not found in other strata. He soon is able to identify a stratum by its fossil content. He does not publish any map until several years later.

1799 Johann Hieronymous Schroeter (1745–1816), amateur astronomer in Germany, records his observations of a transit of Mercury.

1800 Alessandro Volta (1745–1827), Italian physicist, announces his invention of the voltaic pile, which is the first real battery. His work duplicating Galvani's 1791 "animal electricity" experiment leads him to discover that it is the contact of dissimilar metals that causes the electricity. He then arranges suitable pairs of metallic plates in a certain order, separates them by pieces of leather soaked in brine, and creates a "pile" or battery that produces a continuous and controllable electric current.

1800 William Cumberland Cruikshank (1745–1800), Scottish chemist and surgeon, performs electrical experiments and observes the liberation of oxygen and hydrogen at different poles of metal in water. He also invents the galvanic trough, which is an improved voltaic pile.

c.1800 Bartolomeo Ruspini of Italy invents the dental mirror.

1800 Humphry Davy (1778–1829), English chemist, discovers the anesthetic effect of nitrous oxide or laughing gas. It becomes the first chemical anesthetic.

1800 William Herschel (1738–1822), German-English astronomer, first detects infrared radiation from the sun. Although he can detect this form of light, it cannot be seen, and it is not adequately explained for another half-century.

1800 William Nicholson (1753–1815), English chemist, and Anthony Carlisle (1768–1840), English anatomist, discover that water can be decomposed (hydrogen and oxygen separated) by an electric current. Using the new voltaic cell, they use electricity to produce a chemical reaction. Their discovery of electrolysis opens up the new field of electro-chemistry.

1800 Johann Wilhelm Ritter (1776–1810), German physicist, repeats the Nicholson/Carlisle water electrolysis experiment but arranges to collect the two gases (hydrogen and oxygen) separately for the first time. In further experiments this year, he discovers electroplating when he passes an electric current through a solution of copper sulfate and produces metallic copper.

1800 Benjamin Waterhouse (1754–1846), American physician, administers the first vaccinations in the United States. Convinced that Jenner's new vaccination methods are worthwhile, he vaccinates his four children with a virus obtained from England.

1801 William Wollaston, English chemist and physicist, discovers dark (absorption) lines in the solar spectrum, later christened Fraunhofer lines.

1801 Jean Baptiste Lamarck (1744–1829), French naturalist, publishes his *Système des Animaux sans Vertèbres*, which establishes him as the founder of modern invertebrate zoology. He classifies invertebrates according to their respiratory, circulatory, and nervous systems. He claims Earth to be extremely old and says that living organisms change over time.

1801 Johann Wilhelm Ritter (17776–1810), German physicist, discovers the ultraviolet region of the spectrum. Knowing that silver chloride breaks down and turns black in the presence of light, he explores the region beyond the violet and finds that an invisible light also blackens silver chloride. He concludes that radiation must exist that is invisible to the eye.

1801 Nicholas Gautherot (1753–1803), French chemist, discovers that when a current is passed through two plates or wires of the same metal in dilute sulfuric acid, a secondary, reverse or polarization current is obtained after disconnecting the battery. This is an important step toward the storage of electricity.

1801 Thomas Young (1773–1829), English physicist and physician, reads a paper before the Royal Society in which he demonstrates, via his principle of interference, the wave nature of light. This major breakthrough in understanding light is opposed mainly because it refutes Newton's particle theory.

1801 William Hyde Wollaston (1766–1828), English chemist and physicist, establishes that frictional and galvanic electricity are identical. He also discovers, independently of Johann Wilhelm Ritter, the existence of invisible light beyond the violet (ultraviolet light).

1801 Andres Manuel Del Rio (1764–1849), Spanish-Mexican mineralogist, actually discovers vanadium but, unable to convince others that it is not chromium, allows himself to be persuaded and drops his claim to a new metal.

1801 Charles Hatchett (1765–1847), English chemist, discovers columbium, which is later called niobium.

1801 Franz Carl Achard (1753–1821), German chemist, develops Marggraf's sugar-from-beets discovery and opens the first European sugar refinery in Silesia (located in what are now Germany, Czech Republic, and Poland).

1801 John Dalton (1766–1844), English chemist, formulates the law of partial pressures for the components of a gaseous mixture. This states that each component of a mixture of gases exerts the same pressure that it would if it alone occupied the entire volume of the mixture, at the same temperature.

1801 Joseph Jérôme Lefrançais de Lalande (1732–1807), French astronomer, publishes his star catalog of nearly 50,000 stars. In it, he observes Neptune and records its position, but does not realize that it is a planet and not a star.

1801 Matthew Flinders (1774–1814), English navigator, begins his expedition to Australia (1801–1805), where he explores and charts its southeast coast and circumnavigates Tasmania.

1801 René Just Haüy (1743–1822), French mineralogist, publishes his five-volume masterpiece, *Traité de Minéralogie*. Containing 86 stunning plates, this work continues his founding of the science of crystallography.

1801 Robert Hare (1781–1858), American chemist, invents the oxy-hydrogen blowpipe, which is the ancestor of the modern welding torch. With it, Hare is able to melt sizeable quantities of platinum.

1801 Sigismund Friedrich Hermbstaedt (1760–1833), German chemist, discovers sodium bicarbonate. The German chemist Valentin Rose (1762–1807) independently does the same.

1801 Thomas Young (1773–1829), English physicist and physician, who discovers the cause of astigmatism in 1791, is the first to describe the eye condition.

1801 Giuseppe Piazzi (1746–1826), Italian astronomer, discovers what he believes to be a planet located between Mars and Jupiter. During the next few years, he realizes that what he is seeing is really an object that is neither a star nor a planet. What Piazzi discovers is in fact an entire zone of little planets or planetoids now called by the popular name "asteroids." He names the first of these ever to be seen Ceres.

1802 Giovanni Domenico Romagnosi (1761–1835), Italian physicist, performs electrical experiments that result in the deflection of a magnetic needle. Although he precedes Hans Øersted (1777–1851) in this, he does not make the discovery of electromagnetism.

1802 Thomas Young (1773–1829), English physicist and physician, performs his classic experiment on interference in which sunlight is made to pass through two pinholes in an opaque screen. With a wave interpretation of his observations, he is able to provide

the first quantitative values of the length of light waves. He publishes *An Account of Some Cases of the Production of Colours Not Hitherto Ascribed*, in which he describes the principle of interference, using the example of two systems of waves moving on the surface of a lake and forced to flow together, one on top of the other, in a narrow canal.

1802 Anders Gustaf Ekeberg (1767–1813), Swedish chemist, discovers tantalum.

1802 Christian Leopold von Buch (1774–1853), German geologist and one of Abraham Gottlob Werner's main disciples in terms of the debate between the Vulcanists and Plutonists, visits the basalt flows in France and decides that his revered teacher is incorrect. Von Buch then converts to the theory that the basalt rocks are volcanic in origin (Vulcanism).

1802 Domenico Pini Morichini (1773–1836), Italian chemist, discovers calcium fluoride in tooth enamel.

1802 First use of the word "biology," meaning the whole science of living things, is proposed separately by Jean Baptiste Lamarck (1744–1829), French naturalist, and German naturalist Gottfried Reinhold Treviranus (1776–1837).

1802 Jean Baptiste Lamarck (1744–1829), French naturalist, publishes his *Hydrogéologie*, in which he discusses the extreme age of Earth. He says that continental shorelines are transitory and talks about uplift and mountain-building in modern terms.

1802 John Playfair (1748–1819), Scottish mathematician, organizes and rewrites James Hutton's paper containing his theory of uniformitarianism and publishes *Illustrations of the Huttonian Theory of the Earth.* As a close friend and colleague of Hutton, Playfair uses his literary skills to explain his friend's new geological ideas in a logical and lucid manner.

1802 Joseph Louis Gay-Lussac (1778–1850), French chemist, shows for the first time that all gases expand equally or by equal amounts with the same increase in temperature. It becomes known as "Gay-Lussac's law." It is also known as "Charles' law" after Jacques-Alexandre Charles, who noted this law in 1787.

1802 Nathaniel Bowditch (1773–1838), American astronomer and mathematician, publishes his *New American Practical Navigator.* This self-educated astronomer corrects the many errors in the earlier tables published by Moore, and his revised work soon becomes a standard reference work for seamen throughout the world.

1802 Thomas Thomson (1773–1852), Scottish chemist, publishes his *System of Chemistry* and introduces a system of symbols for individual minerals using the first letters of their names.

1802 Thomas Wedgewood (1771–1805), English physicist, publishes *An Account of a Method of Copying Painting Upon Glass, and of Making Profiles by the Agency of Light Upon Nitrate Silver.* In this work he describes his experiments with English chemist Humphry Davy (1778–1829), in which paintings on glass coated with silver nitrate are used as negatives while an image is made on another plate upon exposure to light. Since they do not know how to "fix" this image, it gets progressively darker.

1802 William Hyde Wollaston (1766–1828), English chemist and physicist, examines a candle flame through a prism and is able to distinguish dark lines that cross the spectrum. He does not know that he is one of the first to observe the different wave lengths of light.

1802 William Hyde Wollaston (1766–1828), English chemist and physicist, is the first to note the dark lines in the solar spectrum, but he does not investigate them and assumes they are simply the natural boundaries between the various colors of the spectrum. It is not until Fraunhofer that the significance of these lines are realized

1802 Heinrich Wilhelm Matthaus Olbers (1758–1840), discovers the second asteroid ever found, which he names Pallas.

1802 William Herschel (1738–1822), German-English astronomer, records his observations of the transit of Mercury.

1803 Louis Poinsot (1777–1859), French mathematician, publishes his *Elements de Statique*, which contains his theory of couples (two parallel forces of equal magnitude but opposite direction form a couple). He also introduces the concept of torque.

1803 Alexander von Humboldt (1769–1859), German naturalist, writes an article in which he states that the Atlantic Ocean is a valley dug out by a torrential current.

1803 André Michaux (1746–1802), French botanist, publishes the first book of American flora or plants that is national in scope. His *Flora Boreali-Americana* is published posthumously in Paris and has many plates drawn by French artist Pierre-Joseph Redouté.

1803 Barthélemy Faujas de Saint-Fond (1741–1819), French geologist, publishes his *Essai de Géologie*, in which he states that fossils can be used to date particular strata.

1803 Claude-Louis Berthollet (1748–1822), French chemist, discovers that the manner and rate of chemical reactions depend on more than affinities or the attraction of one substance for another. He shows that reactions are affected by relative quantities and temperature, and that many reactions are reversible. This is the first attempt to consider the physics of chemistry.

1803 Constantin-François Chaseboeuf de Volney (1757–1820), French traveler, publishes a broad geological description of the eastern United States that contains the first color map of that region.

1803 Jöns Jakob Berzelius (1779–1848), Swedish chemist, and Wilhelm Hisinger (1766–1852), Swedish mineralogist, discover cerium, which Martin Heinrich Klaproth (1743–1817) also independently discovers.

1803 Jöns Jakob Berzelius (1779–1848), Swedish chemist, first suggests that acids and bases have opposite electrical charges. He discovers this while experimenting with a new voltaic pile.

1803 Jean-Baptiste Biot (1774–1862), French physicist, finally convinces a skeptical scientific community that meteorites do fall from the heavens. Commissioned by the French Institut National, he travels to L'Aigle, France, where he collects evidence and testimony concerning meteorites.

1803 John Dalton (1766–1844), English chemist, states the law of multiple proportions, which applies to two elements that can combine in more than one way. He also states his atomic theory, which says that all elements are composed of extremely tiny, indivisible, indestructible atoms, and that all the known substances are composed of some combination of these atoms. He finally states that these atoms differ from each other only in mass, and that this difference could be measured.

1803 Lazzaro Spallanzani (1729–1799), Italian biologist, publishes his *Memoires sur la Respiration* in Geneva; in the book he demonstrates that oxygen is converted in the tissues and is transported in the blood.

1803 William Henry (1774–1836), English physician and chemist, determines the effects of pressure on the solubility of gases in liquids.

1803 William Henry (1774–1836), English physician and chemist, proposes what becomes "Henry's law," stating that the amount of gas absorbed by a liquid is in proportion to the pressure of the gas above the liquid, provided that no chemical reaction occurs.

c.1803 William Hyde Wollaston (1766–1828), English chemist and physicist, discovers a method of making platinum malleable, allowing it to be hammered and molded into shape, mainly for laboratory apparatuses. He keeps this process a secret and amasses great wealth. After his death, the secret is released and it forms the basis of modern powder metallurgy.

1804 John Leslie (1766–1832), Scottish physicist and mathematician, publishes *An Experimental Inquiry into the Nature and Propagation of Heat*, in which he shows that the transmission of heat by radiation has the same properties as the propagation of light.

1804 Smithson Tennant (1761–1815), English chemist, discovers iridium (from the Greek word for "rainbow") and osmium (from the Greek word for "smell").

1804 Soybeans are first brought to the United States as ballast in ships.

1804 W. Thomson publishes an article in *Bibliothèque Britannique* in which he first describes the structure of meteorites and also discounts their "celestial origin."

1804 Karl Ludwig Harding (1765–1834), German astronomer, discovers Juno, the third asteroid to be found.

1804 First agricultural fair in America is held in Washington, D.C.

1805 Joseph Louis Gay-Lussac (1778–1850), French chemist, establishes that precisely two volumes of hydrogen combine with one volume of oxygen to form water.

1805 Humphry Davy (1778–1829), English chemist, begins his electrical experiments, producing an electric arc and an extremely strong battery made up of over 250 metallic plates.

1805 Johann Wilhelm Ritter (1776–1810), German physicist, announces that if a current is passed through a solution of copper sulfate, metallic copper can be made to plate out. This marks the beginning of electroplating.

1805 Antoine-François de Fourcroy (1775–1809), French chemist, identifies magnesium phosphate and a substance later known as calcium in bones.

1805 Friedrich Wilhelm Adam Serturner (1783–1841), German chemist, first isolates morphine, the active principle of opium. In doing so, he lays the groundwork for alkaloid chemistry.

1805 Georges Cuvier (1769–1832), French anatomist, defines the brain's medulla and the cortex of the adrenal gland.

1805 Humphry Davy (1778–1829), English chemist, begins a ten-lecture series on geology at London's Royal Institution. This extremely popular series is published the same year.

1805 John Dalton (1766–1844), English chemist, publishes the first table of atomic weights and invents a new system of chemical symbols.

1805 Joseph Louis Proust (1754–1826), French chemist, defends his law of constant or definite proportions over the views of French chemist Claude-Louis Berthollet (1748–1822) who argues wrongly that the constituents of a compound can unite in a continuous range of proportions.

1805 William Dandridge Peck (1763–1822), American naturalist, is elected the first professor of natural history at Harvard University.

1806 Humphry Davy (1778–1829), English chemist, begins a series of Bakerian lectures in England on electrochemistry that presents a critical summary of work to date and further stimulates research in that field.

1806 Gaspard Vieusseux (1746–1814) of Switzerland describes cerebrospinal meningitis.

1806 Humphry Davy (1778–1829), English chemist, performs experiments on electrolysis that lead him to state the electrochemical theory. He also discovers potassium when he passes a current through molten potash. One week later he isolates sodium from soda.

1806 Louis-Nicolas Vauquelin (1763–1829), French chemist, discovers the first amino acid, asparagine, which he isolates from asparagus.

1807 Thomas Young (1773–1829), English physicist and physician, first uses the word "energy" in its modern, scientific sense, meaning the property of a system that makes it capable of doing work.

1807 Thomas Young (1773–1829), English physicist and physician, publishes his *Lectures on Natural Philosophy*, in which he is the first to treat shear as an elastic strain. This marks the beginning of the concept of practical elasticity in the science of materials.

1807 The first American textbook on obstetrics is written by Samuel Bard (1742–1821).

1807 Harvard Botanic Garden is first established in Cambridge, Massachusetts, by American naturalist William Dandridge Peck (1763–1822).

1807 Jean-Antoine-Claude Chaptal (1756–1832), French chemist, publishes his *Chimie Appliquée aux Arts*, which is the

first book devoted specifically to industrial chemistry.

1807 Jean-Nicolas Corvisart (1755–1821), French physician, publishes what becomes an important treatise on the organic lesions of the heart and large vessels.

1807 John Stearns (1770–1848), American physician, first publishes an account of the physiological effects of the drug ergot. He notes the drug's ability to stimulate and strengthen uterine contractions and to constrict small blood vessels.

1807 The Geological Society of London is founded, becoming the first association of its kind in the world. Its first president is George Bellas Greenough (1778–1855) who becomes mainly responsible for its success. By April 1811, the society has 200 members.

1808 Dominique Francois Jean Arago (1786–1853), French physicist, finds the neutral point of reflected light where polarization is absent.

1808 Etienne Louis Malus (1775–1812), French physicist, accidently discovers a phenomenon he calls "polarized light" while sending a ray of light through a doubly refracting crystal. Although he believes light to be made of particles and not waves, he does establish polarization as a general property of light.

1808 First important American work on horticulture is *American Gardener's Calendar*, written by Bernard McMahon (c.1775–1816) and published in Philadelphia. Since 1802 he had been issuing one-page broadsides of nursery items for sale.

1808 Humphry Davy (1778–1829), English chemist, begins a series of experiments that lead to the isolation and identification of barium, strontium, calcium, and magnesium.

1808 John Dalton (1766–1844), English chemist, publishes his *New System of Chemical Philosophy*, in which he elaborates his atomic theory and makes his revolutionary ideas well-known.

1808 Joseph Louis Proust (1754–1826), French chemist, distinguishes among the different sugars in plants and is the first to study glucose, the sugar in grapes.

1809 Amedeo Avogadro (1776–1856), Italian physicist, introduces the concept of the relativity of acids. He states that a substance that is acid relative to another may be alkaline in respect to a third.

1809 Christian Leopold von Buch (1774–1853), German geologist, publishes his *Geognostische Beobachtungen auf Reisen durch Deutschland und Italien*, in which he formulates the hypothesis that the origins of mountains can be attributed to the activity of heat inside Earth.

1809 Ephraim McDowell (1771–1830), American surgeon, performs the first ovariotomy on a woman who is 47 years old. It is successful and she lives to be 78. His success disproves the notion that it is impossible to cut into the abdomen without death resulting and paves the way for later surgery in the abdominal area.

1809 Jean Baptiste Lamarck (1744–1829), French naturalist, introduces the term "invertebrates" in his *Philosophie Zoologique*, which contains the first scientific theory of evolution. He also classifies organisms by function rather than by structure and is the first to employ the genealogical tree.

1809 Johann Karl Friedrich Gauss (1777–1855), German mathematician, publishes his *Theoria Motus Corporum Coelestium*, in which he offers his method of calculating the orbit of a planet using only three complete observations of its position. He uses his unique method of least squares.

1809 Joseph Louis Gay-Lussac (1778–1850), French chemist, collaborates with Alexander von Humboldt (1769–1859), German naturalist, and states the law of gaseous volume. They discover that in forming compounds, gases combine in simple proportions by volume.

1809 William Maclure (1763–1840), American geologist, publishes an article that contains the first frequently reprinted and widely distributed geological map of the eastern coast of the United States.

1809 William Martin (1767–1810), English geologist, publishes his *Outlines of an Attempt to Establish a Knowledge of Extraneous Fossils on Scientific Principles*, in which he offers the principles of scientific paleontology.

1809 Yale Medical School is founded in Connecticut.

1810 John Leslie (1766–1832), Scottish physicist and mathematician, first creates artificial ice as he freezes water using an air pump.

1810 Christian Leopold von Buch (1774–1853), German geologist, prepares the first geologic map of Germany.

1810 Daniel Drake (1785–1852), American physician, first describes the sometimes fatal disease called "milk sickness." The cause is eventually found to be drinking milk from cows that have fed on white snakeroot. Abraham Lincoln's mother, Nancy Hanks Lincoln, is said to have died from this disease.

1810 Franz Joseph Gall (1758–1828), Austrian-French physician, publishes the first of his four-volumes titled *Anatomie et Physiologie du Système Nerveux*, which founds a new discipline, phrenology, the study of cranial protuberances.

1810 Franz Joseph Gall (1758–1828), German physician, first lays the basis for modern neurology with his dissections of the brain and his correct suggestions about nerve organization.

1810 Jöns Jakob Berzelius (1779–1848), Swedish chemist, first shows that the laws of combination and the atomic theory apply in both organic and inorganic chemistry.

1810 Nicolas Appert (1752–1841), French inventor, publishes *L'Art de Conserver... Les Substances Animals et Vegetables*, which founds the commercial canning industry. He describes how to preserve food over long periods of time by putting it in corked and sealed bottles and submerging them in boiling water. He applies heat to kill anything that might cause spoilage and then excludes air. Appert also develops the bouillon cube.

1810 Samuel Hahnemann (1755–1843), German physician, publishes his *Organon der Rationellen Heilkunst*, which offers the first complete exposition of the homeopathic method of health therapy.

1811 Bernard Courtois (1777–1838), French chemist, discovers iodine.

1811 Gustav Schubler (1787–1834), German meteorologist, makes the first known report of the daily periodicity of the intensity of the electricity in the atmosphere.

1811 Simeon-Denis Poisson (1781–1840), French mathematician, develops a mathematical theory of heat.

1811 A series of earthquakes centered in New Madrid, Missouri, first occur. Continuing into 1812, these major quakes alter much of the Midwest's topography and are considered the strongest in U.S. history (estimated at 8.0 on the Richter scale) because they affect such a large area.

1811 Alexandre Brongniart (1770–1847), French mineralogist, and Georges Cuvier (1769–1832), French anatomist, publish their *Essai sur la Géographie Minéralogique des Environs de Paris.* Based largely on Brongniart's research, the two scientists produce geologic maps in color that demonstrate how fossils can be used to determine accurately the geological chronology of a particular area.

1811 Amedeo Avogadro (1776–1856), Italian physicist, first proposes his theory of molecules, which is confirmed much later by modern chemistry. He states that equal volumes of all gases contain the same number of molecules if they are under the same conditions and temperature.

1811 Bernard Courtois (1777–1838), French industrialist, discovers iodine in the ashes of seaweed. The ingestion of burnt seaweed was recommended as a treatment for goiter by Spanish alchemist Arnold of Villanova (c.1235–1311) around 1300 and is known to have been used by the Chinese around 1600 BC.

1811 Charles Bell (1774–1842), Scottish surgeon, differentiates between sensory and motor roots of spinal nerves in his *New Idea of the*

Anatomy of the Brain. He declares that each nerve carries either a motor or sensory stimulus, but not both at once. He also states that the anterior spinal roots of the brain are for motor responses and the posterior are for sensory. He publishes these findings. Bell's Palsy of the facial nerve is named after him.

1811 Elisha North (1771–1843), American physician, publishes the first book on cerebrospinal meningitis (called "spotted fever") and recommends the use of a clinical thermometer.

1811 Heinrich Wilhem Matthaus Olbers (1758–1840), German astronomer, forms a theory that the tail of a comet always points away from the sun because of pressure from the sun's radiation. Radiation pressure from light is not demonstrated until the twentieth century.

1811 Joseph Louis Gay-Lussac (1778–1850) and Louis-Jacques Thénard (1777–1857), both French chemists, determine the elementary composition of sugar for the first time. This is also the first efficient method for analyzing organic matter.

1811 Julien Jean-César Legallois (1770–1814), French physiologist, locates the first physiological center in the brain.

1811 Massachusetts General Hospital is founded.

1811 Pierre-Louis Dulong (1785–1838), French chemist, discovers the highly explosive nitrogen trichloride. During his experiments he loses an eye and nearly a hand in two explosions.

1811 The Geological Society of London publishes its first *Transactions*, containing eighteen articles.

1812 Jean Baptiste Biot (1774–1862), French physicist, experiments with double refraction, or what is now called polarized light, and discovers rotary dispersion. This means that the degree of rotation of the plane of polarization depends on the color of the light. This leads him to other discoveries.

1812 Pierre-Simon Laplace (1749–1827), French astronomer and mathematician, suggests that a complete knowledge of the masses, positions, and velocities of all particles at any given moment would allow the calculation of all events, past and future.

1812 *New England Journal of Medicine and Surgery* is first published.

1812 Benjamin Rush (1745–1813), American physician, publishes his *Medical Inquiries and Observations upon the Diseases of the Mind*, which is the first American treatise on psychiatry.

1812 First independent village medical school is founded in Herkimer, New York. This unique type of one-room medical school was formed in remote areas of the country and had two or three faculty members, usually local doctors.

1812 Friedrich Mohs (1773–1839), German mineralogist, proposes his decimal hardness scale. This is later used to classify minerals by determining their hardness by scratching their surface with a substance of a known hardness.

1812 Gas, Light and Coke Co. is founded in London.

1812 Georges Cuvier (1769–1832), French anatomist, appends his *Discours sur les Révolutions de la Surface du Globe* to his work on fossils published this same year. In this work he attempts to reconcile his geological findings with Biblical accounts. The work is published separately in 1826.

1812 Georges Cuvier (1769–1832), French anatomist, founds vertebrate paleontology with his *Recherches sur les Ossemens Fossiles des Quadrupèdes*. He not only reconstructs many fossil vertebrates, but also states his geological theory that Earth has had a long, peaceful history punctuated by sudden physical changes. In 1817, he divides the animal kingdom into four groups or "Embranchments."

1812 James Sowerby (1757–1822), English natural historian, publishes his *Mineral Conchology of Great Britain*, which becomes a valuable aid to mollusk shell collectors and is still a valuable reference work.

1812 William Hyde Wollaston (1766–1828), English chemist, publishes an article on crystals and also designs the first accurate

reflection goniometer capable of measuring the angles between faces of small crystals.

1812 The Academy of Natural Sciences is founded in Philadelphia. It eventually receives the nation's oldest plant collections and goes on to assemble one of the foremost botanical libraries.

1813 Humphry Davy (1778–1829), English chemist, publishes his *Elements of Agricultural Chemistry*, a pioneering work that becomes the first textbook dealing with the applications of chemistry to agriculture.

1813 Robert Bakewell (1768–1843), American geologist, publishes his *Introduction to Geology*, which is the first successful English textbook on the subject and which sees many editions in the United States.

1813 Thomas Cooper (1759–1839), American chemist, analyzes the density of the minerals that make up Earth's crust and concludes that Earth must have a solid core of magnetic material, probably nickel or iron.

1813 William Charles Wells (1757–1817), American-English scientist, and his colleagues James Cowles Prichard (1786–1848) and William Lawrence (1783–1867) put forward theories of natural selection and repudiate Lamarckism (which says that acquired characteristics are inherited).

1813 The U.S. Congress passes an act establishing a medical department to function during the War of 1812. It provides for a Physician and Surgeon General and an Apothecary General.

1814 First American flora or plant book that is continental in scope and includes species from the Pacific Northwest is *Flora Americae septentrionalis* by Frederick Traugott Pursh (1774–1820). It is published in London.

1814 Joseph von Fraunhofer (1787–1826), German physicist and optician, discovers the lines of the solar spectrum while using a new prism. After studying these solar lines in detail and mapping them, he finds that reflected light from the moon and other planets contains the same absorption lines, but that light from other stars does not. His work lays the foundations of spectroscopy.

1814 The Royal Hospital for Diseases of the Chest is founded in London, England, in an attempt to keep consumptive patients segregated.

1815 David Brewster (1781–1868), Scottish physicist, discovers that a beam of light can be split into a reflected portion and a refracted portion, at right angles to each other, and that both would then be completely polarized. This comes to be known as Brewster's law.

1815 Jean Baptiste Biot (1774–1862), French physicist, discovers that polarized light, when passing through an organic substance, might be rotated clockwise or counterclockwise depending upon the optical axis of the substance. He realizes that it is the molecules in the substance that affect the polarized light.

1815 First bibliography of entomology is compiled by William Elford Leach (1790–1836) of England and published in the *Edinburgh Encyclopedia*.

1815 Humphry Davy (1778–1829), English chemist, invents the safety lamp for coal miners by understanding the properties and nature of methane gas and oxygen.

1815 John Kidd (1775–1851), English physician and chemist, publishes his *Geological Essay*, in which he becomes the first British mineralogist to follow Haüy's classification system.

1815 Joseph Louis Gay-Lussac (1778–1850), French chemist, discovers cyanogen and describes its properties, preparation, and compounds in a paper titled "Recherche sur l'acide prussique."

1815 Michel-Eugène Chevreul (1786–1889), French chemist, isolates sugar from the urine of a diabetic and shows that it is glucose, the same as grape sugar. This a major step in recognizing diabetes as a disease of the body's sugar metabolism.

1815 Thomas Jefferson (1743–1826), former President of the United States, sells his 7,000–volume library to the nation as the nucleus for the Library of Congress, whose collection was burned when the British took Washington, D.C. in 1814. Among his books are 26 botanical titles.

1815 William Prout (1785–1850), English chemist and physiologist, publishes an anonymous article in which he states that the atomic weights of the elements are all integral multiples of that of hydrogen. This later becomes known as "Prout's hypothesis."

1815 William Smith (1769–1839), English geologist, publishes his landmark map, *A Delineation of the Strata of England and Wales with Part of Scotland*, which lays down the principles of paleontological stratigraphy. This geologic map, roughly six by nine feet, is the first attempt to represent on a large scale the geological relations of such an extensive tract of ground. Its color key makes it easily understood.

1815 Mount Tambora in Indonesia explodes, killing an estimated 12,000 people and causing New England to experience "the year without a summer" in 1816.

1816 Louis Cauchy (1789–1857), French mathematician, writes a classic paper on turbulence or the propagation of waves at the surface of a liquid.

1816 Pierre-Simon Laplace (1749–1827), French astronomer and mathematician, formulates a new theory on the velocity of the propagation of sound waves in gaseous media.

1816 Sophie Germain (1776–1831), French mathematician, publishes her paper, "Memoire sur vibrations des lames elastiques," and wins the French Academy of Science's Prix Extraordinaire.

1816 Ignatz Venetz (1788–1859), Swiss civil engineer, publishes an article on glaciers and their movement of erratic boulders, which influences Louis Agassiz (1807–1873). He also states that glaciers once covered most of Europe.

1816 Parker Cleaveland (1780–1858), American geologist, publishes his *Elementary Treatise on Mineralogy and Geology*, which includes the first broad compilation of American mineral occurrences. In 1818, he becomes the first American member of the Geological Society of London.

1817 German pharmacist Frederick Serturner announces the extraction of morphine from opium.

1817 Thomas Young (1773–1829), English physicist and physician, proposes correctly that light waves are transverse (or vibrating at right angles to the direction of travel).

1817 Friedrich Strohmeyer (1776–1835), German chemist, discovers the element cadmium.

1817 Georges Cuvier (1769–1832), French anatomist, publishes his major work *Le Règne Animal*, which extends and perfects the classification system of Carl Linnaeus by grouping related classes into broader groups called phyla. He is also the first to extend this system of classification to fossils.

1817 Johan August Arfvedson (1792–1841), Swedish chemist, discovers lithium.

1818 Jean Fresnel (1788–1827), French physicist, publishes his *Mémoire sur la Diffraction de la Lumière*, in which he demonstrates the ability of a transverse wave theory of light to account for such phenomena as reflection, refraction, polarization, interference, and diffraction patterns. His excellent calculations eventually help convert many of his contemporaries to the wave theory.

1818 Pierre Louis Dulong (1785–1838), French chemist, and Alexis Therese Petit (1791–1820), French physicist, collaborate and show that the specific heat of an element is inversely related to its atomic weight.

1818 Benjamin Silliman (1779–1864), American geologist, founds the *American Journal of Science* and through it becomes the world's best-known American geologist. He introduces Britain's most advanced geological ideas to America and cultivates students who later have a profound effect on American geology.

1818 Friedrich Wilhelm Bessel (1784–1846), German astronomer, publishes his *Fundamenta Astronomiae*, in which he offers the first highly accurate star positions and also establishes the theory of astronomical measurement and reduction of observations.

1818 Jöns Jakob Berzelius (1779–1848), Swedish chemist, discovers selenium, publishes a table of atomic weights, and offers a system of chemical symbolism. His weight table is based on a standard 100 for oxygen and

becomes accepted in the twentieth century. His symbols use one of two letters of the Latin name and are essentially also retained in the twentieth century.

1818 Jean-Louis Pons (1761–1831), French astronomer, detects a comet that proves to have the shortest period of any discovered before or since. During his career, which began as a janitor in the observatory in Marseille, he discovers 37 comets.

1818 Johann Friedrich Meckel (1781–1833), German anatomist, classifies human abnormalities, such as birth defects.

1818 John Ross (1777–1856) of England conducts the first deep-sea study of the ocean floor as he leads an expedition in Baffin Bay (in the Atlantic Ocean between west Greenland and the Canadian Arctic archipelago). He succeeds in bringing up muddy sediments and worms using a "clamp" of his own design. His findings are ignored.

1818 John White Webster (1793–1850) of the United States publishes the first geologic analysis of an American rock.

1818 Louis-Jacques Thénard (1777–1857), French chemist, discovers hydrogen peroxide.

1818 New York Horticultural Society is organized—the first of its kind in America. It is incorporated in 1822 with American physician David Hosack (1769–1835) as its first president.

1818 Pierre-Joseph Pelletier (1788–1842) and Joseph-Bienaimé Caventou (1795–1877), both French chemists, discover strychnine. This is the first alkali of vegetable origin to be discovered after morphine.

1818 Pierre-Louis Dulong (1785–1838), French chemist, and Alexis-Thérèse Petit (1791–1820), French physicist, show that the specific heat of an element is inversely related to its atomic weight. This new law becomes useful in determining atomic weights.

1818 Pieter de Riemer (1760–1831), Scandinavian anatomist, first uses frozen sections in anatomy. Preserving specimens by freezing enables them to be copied from more accurately, with the drawings then used in illustrated anatomical texts.

1818 The beating of the heart is perceived in the fetus.

1818 Valentine Mott (1785–1865), American surgeon, is the first to ligate the innominate artery. This huge artery in the chest provides blood to the right arm as well as to the right side of the head and neck. Being able to tie it off during surgery in this area is necessary if the patient is not to bleed to death.

1818 Xavier Bichat (1771–1802), French physician, publishes his first major work, *Traité des membranes en général*, in which he propounds the notion of tissues. This work also founds histology, distinguishing 21 kinds of tissue and relating disease to them.

1818 Louis-Jacques Thénard (1777–1857), French chemist, reads a paper before the Académie des Sciences announcing his discovery of hydrogen peroxide.

1819 Dominque Francois Jean Arago (1786–1853), French physicist, demonstrates experimentally that light vibrates transversely to its direction of forward movement.

1819 Ami Boué (1794–1881), Austrian geologist, publishes an article in which he writes of metamorphism. This is an important geologic concept in which solid rocks make mineralogical and structural adjustments to physical and chemical conditions that differ from those under which they were originally formed.

1819 Dentists are now making amalgam fillings of mercury and silver.

1819 Eilhardt Mitscherlich (1794–1863), German chemist, discovers isomorphism. This chemical theory states that compounds of similar composition tend to crystallize together, or conversely, that compounds with the same crystal form are analogous in chemical composition. This law becomes useful in establishing atomic weights.

1819 The first distinctively agricultural journal in America, the *American Farmer*, is published in Baltimore, Maryland.

1819 First public health statistics compiled in the United States are the records the Surgeon

General orders kept on troop sickness and mortality. A uniform format allows collation and comparison of data

1819 Jöns Jakob Berzelius (1779–1848), Swedish chemist, publishes his *Essai sur La Théorie des Proportions Chimiques et sur L'Influence Chimique de L'Electricité*, in which he offers his theory of electrochemical dualism. This states that chemical compounds are made up of two components—one charged negatively and the other positively.

1819 Jean-François d'Aubuissons de Voisins (1769–1843), French geologist, publishes his *Traité de Géognosie*, which becomes the first successful French textbook of geology.

1819 Johann Franz Encke (1791–1865), German astronomer, computes the orbital time of a comet discovered by Jean-Louis Pons the year before. Its period proves to be only three and a third years, the shortest ever discovered. Although discovered by Pons, it becomes known as Encke's comet.

1819 John Kidd (1775–1851), English chemist and physician, obtains naphthalene from coal tar, pointing the way toward the use of coal as a source of many important chemicals.

1819 René Théophile Hyacinthe Laennec (1781–1826), French physician, invents the stethoscope and develops diagnosis by auscultation. He announces his discoveries with a publication on this date.

1819 The University of St. Petersburg is founded by Russian Czar Alexander I (1777–1825).

1819 William Buckland (1784–1856), English geologist and professor of mineralogy, is appointed to a teaching position in geology at Oxford University. This is the first such appointment in a major English university.

1820 Hans Christian Ørsted (1777–1851), Danish physicist, experiments with a compass and electricity and demonstrates that a current of electricity creates a magnetic field. He announces his discovery in a short article. This is the first time a real connection can be shown between electricity and magnetism, and it founds the new field of electromagnetism.

1820 Andre Marie Ampere (1775–1836), French mathematician and physicist, extends Hans Christian Ørsted's work and formulates one of the basic laws of electromagnetism. He discovers that two parallel wires, each carrying a current, attract each other if the currents are in the same direction, but they repel each other if in the opposite direction. He concludes that magnetism is the result of electricity in motion.

1820 Johann Salomo Schweigger (1779–1857), German physicist, learns of Ørsted's experiment and realizes that the deflection of the compass needle can be used to measure current strength. He then devises the first rudimentary galvanometer.

1820 Astronomical Society of London is first formed. It later becomes the Royal Astronomical Society.

1820 The first United States *Pharmacopoeia* is published.

1820 Heinrich August von Vogel (1778–1867), German chemist, discovers coumarin. This organic compound smells like new-mown hay (some say like vanilla) and is discovered in the tonka bean (which is native to Guyana).

1820 Jean-François Coindet (1774–1834), Swiss physician, first uses iodine internally in the treatment of goiter and thyroid disorders.

1820 Pierre-Joseph Pelletier (1788–1842) and Joseph Bienaimé Caventou (1795–1877), both of France, first isolate quinine, the active principle of cinchona bark.

1820 The Royal Observatory at Cape Town, South Africa, is established to make observations in the southern hemisphere for comparison with those made at Greenwich, England.

1821 Christopher Hansteen (1784–1873), Norwegian astronomer, conducts research in terrestrial magnetism and discovers a daily variation in the horizontal magnetic intensity.

1821 Joseph von Frauhofer (1787–1826), German physicist and optician, publishes the first of two papers in which he offers the first determination of wavelength. He describes his method of using closely spaced thin wires or gratings to refract

light and how wavelength can be measured via a mathematical relation between the wavelength of diffracted light and the distance between the wires.

1821 Thomas Johann Seebeck (1770–1831), Russian-German physicist, discovers thermoelectricity or the conversion of heat into electricity. He observes that an electric current will flow continuously in a circuit made up of two different metals if they are kept at different temperatures. He does not pursue the implications of what much later is called the "Seebeck effect."

1821 Alexis Bouvard (1767–1843), French astronomer, attempts to calculate the orbit of the newly discovered planet Uranus. He finds that his calculations do not fit the way the planet actually moves, but cannot account for the discrepancy. It is another 20 years before the new planet Neptune is understood as accounting for this phenomenon.

1821 Étienne Geoffroy Saint-Hilaire (1772–1844), French naturalist, publishes his pioneering work on teratology titled *Essai de Classification des Monstres.* This treatise elevates the study of malformations in organisms to a science.

1821 Fearon Fallows (1789–1831), English astronomer, becomes the first Director of the Cape Town Observatory in South Africa.

1821 First international congress of biology is organized by German biologist and physiologist Lorenz Oken (also called Okenfuss; 1779–1851).

1821 François Magendie (1783–1855), French physiologist, founds the *Journal de Physiologie Experimentale.*

1821 Friedlieb Ferdinand Runge (1795–1867), German chemist, discovers caffeine.

1821 Jean-Louis Prévost (1790–1850), Swiss physician, jointly publishes a paper with French chemist Jean Baptiste André Dumas (1800–1884) that demonstrates that spermatozoa originate in tissues of the male sex glands. In 1824 they also give the first detailed account of the segmentation of a frog's egg.

1821 John Macculloch (1773–1835), Scottish chemist and geologist, publishes his work on the classification of rocks. He does much of his geological work while in government service and is regarded as Britain's first official survey geologist.

1821 René Desfosses discovers solanine, a bitter poisonous crystalline alkaloid from the nightshade family of plants.

1821 Thomas Brisbane, the Governor of New South Wales, Australia, establishes an observatory at Paramatta.

1821 Claude Louis Marie Henri Navier (1785–1836), French engineer, publishes his paper titled "Memoire sur les lois de l'Equilibre et du mouvement des corps solides elastiques," which contains the general equations of elasticity. This work lays the foundations for a modern theory of elasticity.

1821 Heinrich Christian Schumacher (1780–1850), German astronomer, founds the *Astronomische Nachrichten*, an important journal in astronomy that is still published today.

1822 Louis Cauchy (1789–1857), French mathematician, works on the mechanics of materials and offers what becomes the origin of the theory of stress.

1822 Jean Baptiste Joseph Fourier (1768–1830), French mathematician, publishes his *Theorie Analytique de la Chaleur*, which is an influential work of mathematical physics. Studying how heat flows from one point to another through a particular object, he offers what becomes known as Fourier's theorem. It proves highly useful in the study of sound, light, and wave phenomena. It also contains the first statement that a scientific equation must involve a consistent set of units, and thus begins dimensional analysis.

1822 Anselme Payen (1795–1871), French chemist, discovers the filtering properties of charcoal in removing impurities from the sugar made from sugar beets. The adsorptive properties of charcoal will be put to use in the gas masks of World War I.

1822 François Magendie (1783–1855), French physiologist, publishes his paper on

"Functions of the Roots of the Spinal Nerves," which lays the foundation for the Bell/Magendie Law.

1822 Friedrich Georg Wilhelm von Struve (1793–1864), German-Russian astronomer, publishes his first estimates of stellar parallax. This is the first calculation of the distance of a star from Earth.

1822 Gideon Algernon Mantell (1790–1852), English physician, and his wife, Mary Ann Mantell, discover in Sussex what proves to be the first fossil to be recognized as a dinosaur.

1822 Jean-Julien d'Omalius d'Halloy (1783–1875), Belgian geologist, gives the name Cretaceous to the latest part of the Mesozoic era.

1822 Willaim Daniel Conybeare (1787–1857) and William Phillips (1773–1828), both English geologists, publish their *Outlines of the Geography of England and Wales.* This highly influential textbook of stratigraphy becomes a basic field manual for British geologists.

1822 William Beaumont (1785–1853), American surgeon, begins his study of digestion after Alexis St. Martin is accidentally shot in the stomach. When St. Martin's wound heals with an opening to his stomach, Beaumont realizes this offers him an opportunity to study digestion first-hand.

1822 The Congregation of the Holy Office repeals the condemnation of Copernican theories that had been issued over two hundred years before. The works of Copernicus are finally taken off the *Index Librorum Prohibitorum* in 1835.

1823 The British medical journal *Lancet* is first founded.

1823 Charles Macintosh (1766–1842), Scottish chemist and inventor, invents waterproofing by spreading dissolved rubber between two sheets of cotton. He dissolves rubber in low-boiling naphtha and creates the "Macintosh" or raincoat.

1823 Jöns Jacob Berzelius (1779–1848), Swedish chemist, discovers silicon.

1823 Justus von Liebig (1803–1873) and Friedrich Wohler (1800– 1882), both German chemists, make a simultaneous discovery of isomerism. In this intriguing concept, two or more compounds can have the same chemical formula yet have different structures and properties.

1823 Karl Caesar von Leonhardt (1779–1862), German mineralogist and geologist, publishes his *Characteristik der Felsarten*, in which he offers the first consistent classification of rocks.

1823 Michael Faraday (1791–1867), English physicist and chemist, devises methods for liquefying gases under pressure and is the first to produce laboratory temperatures below zero Fahrenheit.

1823 Michel-Eugène Chevreul (1786–1889), French chemist, publishes his classic work, which deals with oils, fats, and vegetable colors. He shows that fat is a compound of glycerol with an organic acid. This is one of the first works addressing the issue of the fundamental structure of a large class of compounds, and it has a revolutionary effect on the soap and candle industries.

1824 Nicolas-Leonard Sadi Carnot (1796–1832), French physicist, publishes his *Reflexions sur la Puissance Motrice du Feu*, in which he is the first to consider quantitatively the manner in which heat and work are interconverted. This highly original work also introduces the important concept of cyclic operations and the principle of reversibility. Although this work founds the science of thermodynamics, or the movement of heat, it is neglected for ten years.

1824 First preservation of meat in cans is made.

1824 Johann Franz Encke (1791–1865), German astronomer, calculates the distance from Earth to the sun at 95.5 million miles. This is fairly close to the actual value.

1824 Karl Gustav Carus (1789–1869), German physiologist and psychologist, first sees polar bodies, which are one of the minute cells that separate from the egg during its maturation.

1824 Marie-Jean-Pierre Flourens (1794–1867), French physiologist, first proves that the brain's respiratory center lies low in the

brainstem. A pioneer of the idea of nervous coordination, he is also the first to recognize the role of the inner ear in maintaining body equilibrium and coordination.

1824 René-Joachim-Henri Dutrochet (1776–1847), French physiologist, discovers that tissue is made from living cells.

c. 1825 Dominique Francois Jean Arago (1786–1853), French physicist, runs a current through a copper wire and magnetizes it, demonstrating that iron alone is not necessary for the development of a magnetic force..

1825 William Sturgeon (1783–1850), English physicist, invents and demonstrates the first electromagnet. He begins with Ampere's work and goes further, wrapping a wire scores of times around an iron core that is shaped like a horseshoe. When he sends a current through the wire, each coil reinforces the other, since they form parallel lines with the current running in the same direction. The resulting strong magnetic force can lift nine pounds or twenty times its weight.

1825 Caleb Hillier Parry (1755–1822), English physician, has his observation and first correct description of exophthalmic goiter published posthumously this year. It later becomes known as "Parry's disease."

1825 Hans Christian Ørsted (1777–1851), Danish physicist, isolates aluminum through a four-step process that involves a vacuum.

1825 Jan Evangelista Purkinje (1787–1869), Czech physiologist, first describes the "germinal vesicle" or nucleus in a hen's egg.

1825 John Frederick Herschel (1792–1871), English astronomer, invents the actinometer, which can measure the intensity of solar radiation.

1825 Michael Faraday (1791–1867), English physicist and chemist, discovers benzene, which later proves to be the starting point for understanding organic chemistry.

1825 Michel Eugène Chevreul (1786–1889), French chemist, and Joseph Louis Gay-Lussac (1778–1850), French chemist, employ Chevreul's earlier (1823) understanding of fats and take out a patent for the manufacture of candles from fatty acids. These new candles are harder than the old tallow candles and give a brighter light. This is hailed as a major achievement by the mid-eighteenth century.

1825 Pierre-Fidèle Bretonneau (1778–1862), French physician, performs the first successful tracheotomy for croup. This emergency cut made into the larynx allows a child whose windpipe has swollen shut to breathe.

1825 Thomas Drummond (1797–1840), English engineer, and Goldsworthy Gurney (1793–1875), English inventor, independently produce limelight. They discover that heating lime in an alcohol flame burned in oxygen-rich air makes a stunningly bright artificial light. Drummond uses a parabolic mirror to reflect this light and turns it into a spotlight. Impractical for street lighting, it later is used to illuminate stages in the theater.

1826 Andre Marie Ampere (1775–1836), French mathematician and physicist, publishes his *Memoire sur la Theorie Mathematique des Phenomenes Electro-dynamiques*, in which he offers the mathematical laws that govern the new field of electricity in motion and founds the study of electrodynamics.

1826 Claude Louis Marie Henri Navier (1785–1836), French engineer, publishes his *Resume...sur L'Application de la Mécanique a L'Etablissment des Constructions et des Machines*, which is the first sound textbook on the mechanics of materials. It also contains the flexure formula.

1826 Antoine-Jérôme Balard (1802–1876), French chemist, discovers bromine and demonstrates that its nature and properties are analogous to iodine and chlorine.

1826 Heinrich Wilhelm Matthaus Olbers (1758–1840), German astronomer, points out that if there were an infinite number of stars evenly distributed in space, the night sky should be uniformly light. He accounts for the dark night sky by saying that dust obscures most of the light. This is known as "Olbers paradox." Astronomers had to

wait until the twentieth century to learn that a "red shift" weakened the light of distant stars and kept the night sky dark.

1826 Jean Baptiste André Dumas (1800–1884), French chemist, develops a method for determining the molecular weight of a vapor from its density. It is still used today.

1826 Johannes Peter Müller (1801–1858), German physiologist, discovers that sensory nerves can interpret an impulse in only one manner. The example is the optic nerve, which registers a flash of light however it is stimulated (by light or not).

1826 Leopoldo Nobili (1784–1835), Italian physicist, describes the colorful rings that form electrolytically in a lead and salt solution. These are later called "Nobili's rings."

1826 Otto Unverdorben (1806–1873), German chemist, first prepares aniline by distilling the indigo plant.

1826 Pierre-Fidèle Bretonneau (1778–1862), French physician, describes and names diphtheria in his specification of diseases.

1826 Pierre-François-Olive Rayer (1793–1867), French physician, is the first to distinguish acute from chronic eczema.

1826 René-Joachim-Henri Dutrochet (1776–1847), French physiologist, conducts the first quantitative experiments on osmosis. He determines that the pressures involved during the diffusion of solutions are proportional to the solution concentrations. He is also the first to observe the motion of particles suspended in a liquid, later called Brownian motion.

1826 Wilhelm von Biela (1782–1856), Austrian astronomer, discovers a comet with a seven-year period that becomes known as "Biela's comet." When it comes around for its 1846 pass however, he discovers it has split in two. By 1872, it had become only a small crowd of meteors. This is the first time astronomers are able to watch a member of the solar system die before their eyes. It also offers evidence that there is a connection between comets and meteors.

1827 Georg Simon Ohm (1787–1854), German physicist, experiments with electricity using wires of different length and diameter and discovers that a long, thick wire passes less current than a short, thin wire. He states what becomes Ohm's law: The amount of current passing through a wire is inversely proportional to the thickness of a wire.

1827 Jacques Babinet (1794–1872), French physicist, suggests a new standard of length measurement be adopted. Since all standards to this point are based on uncertain and changeable units, he suggests that something unalterable and true, like the wavelength of some particular type of light ray, be used. It is not until 1960 that technology advances to the point where his suggestion becomes fact.

1827 William Rowan Hamilton (1805–1865), Irish mathematician, publishes his *Theory of Systems of Rays*. This mathematical study of optics contains the correct prediction of conical refraction and helps establish the wave theory of light

1827 Alexandre Brongniart (1776–1847), French mineralogist, publishes his *Classification et Caractères Mineralogiques des Roches Homogènes et Hétérogènes*, in which he is the first to distinguish minerals from rocks.

1827 Felix Savary (1797–1841), French physicist, uses Newton's law of gravitation and shows that binary (double) stars obey the movements predicted by that law. This is the first calculation of the orbit of a binary star.

1827 Friedrich Wohler (1800–1882), German chemist, first isolates metallic aluminum and describes its properties. He discovers beryllium in 1828.

1827 George J.D.P. Scrope (1797–1876), English geologist, publishes his *Memoir on the Geology of Central France*. His astute observations on the age of these volcanoes in the Auvergne influence Charles Lyell who travels there to see for himself. His writings constitute the first extensive study of the nature and effects of volcanic action.

1827 Richard Bright (1789–1858), English physician, publishes his *Reports of Medical Cases*, which contains the first original description of the kidney disease called

nephritis. He also describes a chronic disorder of the kidney that becomes known as "Bright's disease."

1827 William Prout (1785–1850), English chemist and physiologist, first classifies the components of food into carbohydrates, fats, and proteins. He uses the words saccharinous, oleaginous, and albuminous for the three respective groups.

1827 Publication of the first issue of Monthly Notices of the Royal Astronomical Society (MNRAS), a primary research journal in astronomy and astrophysics.

1828 Caroline Lucretia Herschel (1750–1848), German-English astronomer, publishes her *Reduction and Arrangement in the Form of a Catalogue in Zones of all the Star Clusters and Nebulae Observed by Sir William Herschel.*

1828 First American book dealing exclusively with flowers, Robin Green's *Treatise on the Cultivation of Flowers*, is published in Boston.

1828 Friedrich Wohler (1800–1882), German chemist, first synthesizes urea and lays the foundations (along with Berzelius, Liebig, and Bunsen) of organic chemistry and then later of biochemistry. His preparation of an organic compound from inorganic materials dispels the notion that organic compounds can only be produced by using living organisms.

1828 Karl Ernst von Baer (1792–1876), German-Russian embryologist, publishes his landmark *Über die Entwickelungsgeschichte der Thiere* (2 volumes, 1828– 1837) and discovers the mammalian egg. With this, he shows that mammal development, and consequently human development, is not fundamentally different from that of other animals. He also offers his germ-layer theory and his notion of corresponding stages. His book becomes the first text of comparative embryology.

1828 Luigi Rolando (1773–1831), Italian anatomist, achieves the first electrical stimulation of the brain.

c. 1828 Robert Brown (1773–1858), Scottish botanist, observes a small body within the cells of plant tissue and names it a "nucleus." He also discovers what comes to be called "Brownian movement" in plants. This is explained a generation later by the kinetic theory of gases.

1829 Gustave Gaspard de Coriolis (1792–1843), French physicist, publishes *Du Calcul de L'Effet des Machines* in which he introduces the terms "work" and "kinetic energy" and is the first to give them their modern scientific definitions. The kinetic energy of an object is defined as half its mass times the square of its velocity. Work done upon an object is equal to the force upon it multiplied by the distance it is moved against resistance.

1829 Joseph Henry (1797–1878), American physicist, develops a greatly improved form of electromagnet by insulating each wire wound about the metal core and by adding more coils closer together. His electromagnet is far more powerful than Sturgeon's (1825) and can lift 750 pounds.

1829 Leopoldo Nobili (1784–1835), Italian physicist, invents the thermopile or thermomultiplier, a sensitive instrument for measuring heat. Based on the Seebeck effect, it is soon improved and has wider applications.

1829 Alexandre Brongniart (1770–1847), French mineralogist, and Alexander von Humboldt (1769–1859), German naturalist, establish the name Jurassic to designate that period of the Mesozoic era between the Triassic and the Cretaceous. The name comes from the Jura mountains between France and Switzerland.

1829 First school for the blind is founded in Boston by John Dix Fisher (Perkins School).

1829 Jöns Jakob Berzelius (1779–1848), Swedish chemist, discovers thorium, which he names after the Scandinavian god Thor.

1829 Johann Wolfgang Dobereiner (1780–1849), German chemist, proposes his "law of triads," which is based on the relation between an element's properties and its atomic weight number. His idea is ahead of its time and foreshadows Dmitri Mendeleyev's periodic table (1869).

1829 Lardner Vanuxen (1792–1848), American geologist, publishes an article in which he states that rocks could unequivocally be identified by their fossils, position, and mineral content. He also proposes a new stratigraphic nomenclature based on local geographic names.

1829 Thomas Addison (1793–1860), and John Morgan (1797–1847), both English physicians, publish the first book in English on the action of poisons in the living body.

1829 William Nicol (1768–1851), English physicist, announces his invention of the polarizing microscope in a two-page article. He develops a method of making thin sections of minerals and fossil wood, which he then examines on the new microscope. This is called microscopic petrography.

1830 Amos Eaton (1776–1842), American geologist, publishes his *Geological Text-Book*. Eaton's many small, affordable geology texts make his subject accessible and increasingly popular in the United States.

1830 Boston Society of Natural History is founded. With Thomas Nuttall (1786–1859) as its first president, the Society incorporates the C.J. Sprague and Thomas Taylor lichens and the Francis Boott collections.

1830 Charles Lyell (1797–1875), Scottish geologist, publishes the first volume of *The Principles of Geology*. Written in three volumes, this landmark work is very well received and serves to popularize Hutton's ideas of what the proper time scale of geology should be. He eloquently and persuasively documents his argument that there exists a continuity of life and a natural process in the physical world. This work greatly influences Charles Darwin, who said, "I always feel as if my books came half out of Lyell's brain."

c. 1830 First herpetarium in Europe is founded by André M. Dumeril (1774–1860) in France.

1830 Heinrich Georg Bronn (1800–1862), German geologist, founds the *Jahrbuch für Mineralogie, Geognosie, und Petrefaktenkunds* in Heidelberg. He hopes this publication will speed up and bring together scientific communication of geological and paleontological information.

1830 Jöns Jakob Berzelius (1779–1848), Swedish chemist, introduces the scientific terms isomer, polymer, empirical formula, and rational formula.

1830 Johann Franz Encke (1791–1865), German astronomer, is the first to develop a method for computing the orbits of double stars.

1830 Karl von Reichenbach (1788–1869), German naturalist, discovers paraffin.

1830 Nils Gabriel Sefstrom (1787–1845), Swedish chemist, discovers vanadium. It is isolated by English chemist Henry Enfield Roscoe (1833–1915) in 1869.

1830 Proceedings of the Zoological Society of London are first published.

1830 Joseph Henry (1797–1878), American physicist, discovers the principle of electromagnetic induction, showing how an electric current in one coil may set up a current in another through the development of the magnetic field. He puts off further work on this discovery until the following summer, and in the intervening time, the English physicist and chemist Michael Faraday (1791–1867) publishes his discovery first.

1831 Macedonio Melloni (1798–1854), Italian physicist, improves the thermopile of Nobili (1829) and conducts a series of investigations on the nature and properties of radiant heat. He learns that like light, it can be reflected, refracted, and polarized and can give rise to interference effects. In 1850, he shows that infrared light acts the same way also.

1831 Michael Faraday (1791–1867), English physicist and chemist, discovers electromagnetic induction. After laboring for ten years to achieve the opposite of what Oersted had done—to convert magnetism into electricity—he finally produces for the first time an induction current using a magnet. This is the first electric generator. With such a device, mechanical energy can be converted into electrical energy.

1831 Charles Robert Darwin began his historic voyage on the H.M.S. *Beagle* (1831–1836).

His observations during the voyage lead to his theory of evolution by means of natural selection.

1831 Etienne-Geoffroy Saint-Hilaire (1772–1844), French naturalist, publishes his *Recherches sur les Grandes Sauriens Trouvées...l'Etat, Fossile*, which comes to be regarded as the beginning of evolutionary paleontology.

1831 Heinrich Samuel Schwabe (1789–1875), German astronomer, draws a picture of Jupiter on which the "great red spot" is shown for the first time.

1831 Justus von Liebig (1803–1873), German chemist, Eugène Soubeiran (1793–1858), French pharmacologist, and Samuel Guthrie (1782–1848), American chemist, independently discover chloroform.

1831 Pierre-Jean Robiquet (1780–1840), French apothecary, and Jean-Jacques Colin (1784–1865), French chemist, discover the red dye alizarin which they isolate from the root of the common madder plant.

1831 Robert Brown (1773–1858), Scottish botanist, recognizes the cell nucleus as a regular feature of all plant cells.

1831 Thomas Graham (1805–1869), Scottish physical chemist, discovers that the rate of diffusion of a gas is inversely proportional to the square root of its molecular weight. This is called "Graham's law" and is one of the founding principles of physical chemistry.

1831 Patrick Mathew included a discussion of evolution and natural selection in his book *On Naval Timber and Arboriculture.* Matthew later claimed priority in the discovery of evolution by means of natural selection in an article published in 1860 in the journal *Gardeners' Chronicle.*

1832 Michael Faraday (1791–1867), English physicist and chemist, announces what become known as Faraday's laws of electrolysis. He states that the mass of a substance decomposed by an electric current is proportional to the length in time and magnitude of the electric current producing the electrolysis. This establishes the very close connection between electricity and chemistry.

1832 Anselme Payen (1795–1871), French physiologist, first isolates diastase, which he separates from barley. This substance has the property of hastening the conversion of starch into sugar and is an example of the organic catalysts within living tissue (which eventually come to be called enzymes). Its discovery is therefore the first known enzyme.

1832 British Medical Association is founded.

1832 David Brewster (1781–1868), Scottish physicist, discovers "atmospheric lines" in the solar spectrum, which leads him to found research into the absorptive effects of atmosphere on light.

1832 Heinrich Wilhelm Ferdinand Wackenroder (1798–1854), German chemist, discovers carotene (carotin) in carrots. This organic compound is usually found as pigments in plants, giving them a yellow, red, or orange color, and is converted in the liver of animals into vitamin A.

1832 Jean Baptiste André Dumas (1800–1884), French chemist, and his assistant, Auguste Laurent (1807–1853), discover anthracene. Found in coal tar, it is eventually used for the manufacture of dyestuffs.

1832 Joseph Louis Gay-Lussac (1778–1850), French chemist, introduces into chemical practice the concept and practice of titration. This method can determine the concentration of a dissolved substance in terms of the smallest amount of a reagent of a known concentration that is required to bring about a certain effect in reaction with a known amount of the test solution.

1832 Justus von Liebig (1803–1873), German chemist, founds the chemical journal *Annalen der Pharmacie.* It is eventually renamed *Annalen der Chemie.*

1832 Michael Faraday (1791–1867), English physicist and chemist, announces what are now called "Faraday's laws of electrolysis." These two principles establish the intimate connection between electricity and chemistry and place the discipline of electrochemistry on a modern basis.

1832 Pierre-Jean Robiquet (1780–1840), French apothecary, discovers codeine.

1832 Richard Owen (1804–1892), English anatomist and paleontologist, publishes his classic study of the rare nautilus titled *Memoir of the Pearly Nautilus.*

1833 Heinrich Friedrich Emil Lenz (1804–1865), Russian physicist, discovers that the manner in which the resistance of a metallic conductor changes with temperature. It increases with a temperature rise and decreases with a drop.

1833 Jean Baptiste André Dumas (1800–1884), French chemist, uses the combustion method to determine organic nitrogen. This analytical method helps to make organic analysis more quantitative.

1833 Johann Karl Friedrich Gauss (1777–1855), German mathematician, introduces a measurement of terrestrial magnetism that is expressed in absolute units. This is the first time such units—length, mass, and time—are used outside mechanics.

1833 William Rowan Hamilton (1805–1865), Irish mathematician, publishes *On a General Method of Expressing the Paths of Light, and of Planets, by the Coefficients of a Characteristic Function*, which is his attempt to put all optical knowledge in mathematical form.

1833 Edward Hitchcock (1793–1864), American geologist, publishes his *Final Report on the Geology of Massachusetts.* This survey is the first major U.S. book published by a state survey and includes the first geological map of an American state.

1833 The first *U.S. Dispensary* is published.

1833 Jean Louis Rodolphe Agassiz (1807–1873), Swiss-American naturalist, publishes his classic work on fossil fishes, *Recherches sur les Poissons Fossiles.* In this very large work, which eventually reaches five volumes, Agassiz maintains that the successive changes in fish noted in the fossil record correspond with those of the developing embryo.

1833 Johannes Peter Müller (1801–1858), German physiologist, publishes his *Handbuch der Physiologie des Menschen.* This work views the human body as a machine and outlines a path for the systematic experimental study of physiology.

1833 Johannes Peter Müller (1801–1858), German physiologist, first offers his law of specific nerve energies. This states that every sensory nerve gives rise to one form of sensation, even if excited by stimuli other than the normal.

1833 Karl von Reichenbach (1788–1869), German naturalist, discovers creosote.

1833 Philipp Lorenz Geiger (1785–1836), German pharmaceutist, and his colleague Hesse first isolate atropine from belladonna.

1833 William Beaumont (1785–1853), American surgeon, publishes his *Experiments and Observations on the Gastric Juice and the Physiology of Digestion*, which is based on over 200 experiments conducted on his patient Alexis St. Martin.

1834 Benoit Pierre Clapeyron (1799–1864), French engineer, studies the long-ignored work of Carnot (1834) and publishes his mathematical treatment of that nonmathematical work. His work offers a new presentation of Carnot's work and arrives at an equation that involves the relationship of the heat of vaporization of a fluid, its temperature, and the increase in volume involved in its vaporization. This equation contains what later becomes the second law of thermodynamics.

1834 Charles Wheatstone (1802–1875), English physicist, devises a rotating mirror technique that he uses unsuccessfully to measure the speed of electricity through a conductor. This is later used by Armand-Hippolyte-Louis Fizeau in 1849 to measure the speed of light.

1834 Heinrich Friedrich Emil Lenz (1804–1865), Russian physicist, investigates electrical induction and discovers that a current induced by electromagnetic forces always produces effects that oppose those forces. This is the first general description of what is called self-induction, and becomes known as Lenz's law.

1834 Jean Charles Athanase Peltier (1785–1845), French physicist, discovers that at the junction of two dissimilar metals, an electric current will produce heat or cold,

depending on the direction of current flow. This comes to be known as the Peltier effect and is eventually put to use in refrigeration.

1834 William Rowan Hamilton (1805–1865), Irish mathematician, publishes his *First Essay on a General Method in Dynamics*, in which he attempts to mathematicize all of mechanics.

1834 Anselme Payen (1795–1871), French chemist, separates a starch-like substance from wood. Because he obtains it from the cell walls, he names it "cellulose."

1834 Eilhardt Mitscherlich (1794–1863), German chemist, first prepares nitrobenzene. He treats benzene with fuming nitric acid to produce this compound, which is later used in perfumes.

1834 Friedlieb Ferdinand Runge (1795–1867), German chemist, discovers phenol or carbolic acid and prepares it by distilling coal. He also isolates from coal tar a substance he calls Kyanol (later called aniline). This remains the primary industrial source of aromatic compounds until the end of World War I.

1834 Friedrich August von Alberti (1795–1878), German geologist, introduces the term Triassic to his stratigraphic system.

1834 Jean Baptiste André Dumas (1800–1884), French chemist, offers his "type" theory of organic structure, in which he suggests that the chemical properties of an organic compound might not be totally dependent on electrical properties (its positive or negative charge).

1834 Johann von Charpentier (1786–1855), German-Swiss mining engineer, is one of the first to propose the idea of the extensive movement of glaciers. He suggests that the huge erratic boulders found scattered throughout the Alpine regions had been brought there by ancient glaciers. He precedes Agassiz in this notion.

1834 Justus von Liebig (1803–1873), German chemist, revises the chemical symbolism of Berzelius and replaces his superscripts with subscripts. Now the number after the letter comes below it and not above it.

1834 Samuel George Morton (1799–1851), American physician, writes his *Illustrations of Pulmonary Consumption*, which is the first book on tuberculosis issued in the United States.

1834 First constituted dental society in the world, the Society of Surgeon-Dentists of the City and State of New York, is founded.

1835 Gustave Gaspard de Coriolis (1792–1843), French physicist, considers mathematically and experimentally the matter of motion on a spinning surface. He describes what comes to be called Coriolis forces; this becomes a concept of major significance to the study of meteorology, ballistics, and oceanography.

1835 Jean Baptiste Biot (1774–1862), French physicist, founds polarimetry. He shows with his knowledge of polarized light how the hydrolysis (chemical decomposition in water) of sucrose can be followed by noting the changes in optical rotation.

1835 Gabriel Gustav Valentin (1810–1883), German physiologist, publishes the first textbook on human development—*Manual of the Development of the Foetus.*

1835 George Biddell Airy (1801–1892), English astronomer and mathematician, is appointed seventh Astronomer Royal, a post he holds for over 45 years. During his tenure, he modernizes the Greenwich Observatory, bringing it to a level matching the best German observatories.

1835 Halley's Comet makes its second predicted return.

1835 Heinrich Georg Bronn (1813–1862), German geologist, publishes his *Lethaea Geognostica*, a comprehensive work in which he seeks to establish a chronological sequence of fossil organisms.

1835 Jöns Jakob Berzelius (1779–1848), Swedish chemist, first coins the term "catalysis" to describe the agent that brings about a chemical reaction or transformation.

1835 Jacob Bigelow (1787–1879), American physician, publishes his book *On Self-Limited Diseases*, in which he states the commonsense idea that some diseases will simply

run their course and subside without the benefit of any treatment from a physician.

1835 Pierre-Charles-Alexandre Louis (1787–1872), French physician, founds medical statistics (as opposed to vital statistics). Louis believes that keeping statistics can be as valuable as experimenting and encourages his colleagues to keep accurate records.

1835 The Ordnance Geological Survey is established in Britain. It later becomes the Geological Survey of Great Britain.

1835 Theodor Schwann (1810–1882), German physiologist, discovers pepsin, the active digesting principle in the stomach.

1836 Felix Dujardin (1801–1860), French zoologist, describes the "living jelly" of cytoplasm, calling it "sarcode."

1836 John Frederic Daniell (1790–1845), English chemist and meteorologist, designs an improved electric cell that supplies an even current with continuous operation. Made of copper and zinc, the Daniell cell is a major improvement over the Voltaic cell and is the first reliable source of electric current.

1836 Ottaviano Fabrizio Mossotti (1791–1863) of Italy publishes his *Sur les Forces qui Regissent la Constitution Interieure des Corps.* Convinced that all of physical science must be reduced to the laws of motion, he proposes to use molecular mechanics to arrive at a general theory that will unite optics, thermology, and electricity under a single law of nature.

1836 Adam Sedgwick (1785–1873), English geologist, publishes one of his many papers on ancient rocks. During his investigations, he gives the name Cambrian (from the ancient name for Wales) to the oldest fossil-bearing rocks.

1836 Asa Gray (1810–1888), American botanist, publishes his first book, *Elements of Botany*, in New York.

1836 Edmund William Davy (1785–1857), Irish chemist and cousin of English chemist Humphry Davy (1778–1829), discovers and prepares acetylene by the action of water on the residue (potassium carbide) from the preparation of potassium carbonate and carbon.

1836 Joseph Lovell (1788–1836), Surgeon General of the United States, establishes a collection of medical and scientific books that becomes the nucleus of the library of the Surgeon General's Office. In 1956 this collection becomes part of the National Library of Medicine.

1836 Lambert-Adolphe Quételet (1796–1874), Belgian astronomer and statistician, publishes the results of his research comparing the number of shooting stars observed on different nights of the year. He points out the presence of several maximum points that correspond to swarms. Two years later he notes the periodicity of shooting stars in August (Perseids).

1836 Theodor Schwann (1810–1882), German physiologist, allows only heated air to enter a media flask and finds that no growth occurs. He also demonstrates that alcoholic fermentation depends on yeast. This same conclusion is reached independently by Charles Caignard de la Tour (1777–1859).

1836 Theodor Schwann (1810–1882), German physiologist, discovers the fermentive property of pepsin.

1836 William Buckland (1784–1856), English geologist, publishes his *Geology and Mineralogy Considered with Reference to Natural Theology*, which is the last major geological textbook to be written from the diluvialist (great flood) point of view.

1836 Wilhelm Beer (1797–1850), German astronomer, publishes a map of the moon, based on his eight years of observation. This highly accurate map is one meter in diameter and shows the principal features of the moon. He concludes that the moon is a long-dead, static place.

1836 Francis Bailey (1774–1844), English astronomer, describes an effect he observes during an eclipse in which just before the last sliver of sunlight disappears behind the moon, it appears to break into bits and pieces (later called "Bailey's beads"). The same phenomenon occurs on Earth at sunrise when sunlight first breaks through between mountains.

1837 Charles Robert Darwin (1809–1882), English naturalist, publishes an article following his five-year voyage of scientific exploration in which he states that the coast of Chile was elevated by an earthquake in 1835. He also discusses coral atolls and their growth.

1837 Claude-Servais-Mathias Pouillet (1790–1868), French physicist, arrives at a formula by which he attempts to measure the heat of the sun.

1837 Edouard-Armand-Isidore-Hippolyte Lartet (1801–1871), French paleontologist and archeologist, discovers the jawbone of a fossil primate and effectively founds human paleontology.

1837 French physiologist René–Joachim Dutrochet (1776–1847) publishes his research on plant physiology. He is the first to conduct a systematic investigation of osmosis (which he names). He recognizes the importance of this phenomenon, as well as the fact that chlorophyll is necessary to photosynthesis.

1837 Friedrich Georg Wilhelm von Struve (1793–1864), German-Russian astronomer, publishes his catalog of 3,112 double stars, three-fourths of which were unknown prior to his studies.

1837 James Dwight Dana (1813–1895), American geologist, publishes his *System of Mineralogy*, which becomes an authoritative text on minerals throughout the world.

1837 Johann Franz Encke (1791–1865), German astronomer, discovers a small gap within the outermost ring of Saturn. It becomes known as Encke's division.

1837 Karl Bogislaus Reichert (1811–1883), German anatomist and embryologist, describes homologies of middle-ear ossicles.

1837 Karl Theodor Ernst von Siebold (1804–1885), German zoologist, and his colleague Michael Sars (1805–1869) describe division of invertebrate eggs.

1837 Pierre-François-Olive Rayer (1793–1867), French physician, is the first to describe the disease glanders as found in man and to prove that it is not a form of tuberculosis.

1837 Robert Remak (1815–1865), Polish-German physician, notes the true relationship of nerve cells to nerve fibers and first names the neurolemma (the myelin sheath around many nerve fibers). He also offers names that are still used for the three germinal layers in the developing embryo: ectoderm (outer skin), mesoderm (middle skin), and endoderm (inner skin).

1837 Samuel Finley Breese Morse (1791–1872), American artist and inventor, applies for a patent on the single-wire telegraph that uses an electromagnet for transmitting signals. He also describes a new alphabet type that comprises the marking of dots and dashes instead of a zigzag line as previously used (Morse code).

1837 Wilhelm Beer (1797–1850), German astronomer, makes the first complete map of the planet Mars. It establishes the point of departure for longitude that is still in use today. It also shows no canals.

1838 Amanz Gressly (1814–1865), Swiss geologist, writes an article, "Observations Géologiques sur le Jura Soleurois," in which he applies the geologic concept of *facies* (the sum total of the organic and inorganic characteristics of a sedimentary formation) to sedimentary rock.

1838 Angelo Dubini (1813–1902), Italian physician, discovers *Ankylostoma duodenale*, the cause of hookworm disease, in the intestinal tract.

1838 Charles Lyell (1797–1875), Scottish geologist, publishes his hugely successful textbook, *The Elements of Geology*.

1838 Christian Friedrich Schönbein (1799–1868), German physical chemist, publishes an article in which he first uses the word "geochemistry" to describe the study of the chemical and physical properties of rock formations.

1838 Christian Gottfried Ehrenberg (1795–1876), German biologist, begins to publish the results of his microscopic work on fossils. He founds micropaleontology (the study of fossil microorganisms) after discovering the microscopic fossil organism content of various geological formations.

1838 Edward Sabine (1788–1883), British physicist, publishes his *Report on the Variations of the Magnetic Intensity Observed at Different Points of Earth's Surface.* It is this report that motivates the British government to establish magnetic observatories in many of its colonies. Sabine later uses this data in his sunspot work.

1838 First U.S.-government sponsored world expedition sails. Lt. Charles Wilkes (1798–1877) leads a fleet of six naval vessels staffed with nine "scientific gentlemen." The fleet returns in June 1842, having crisscrossed the Pacific, mapped whaling grounds, observed and described the aborigines, and collected 9,674 species of plants and some animals.

1838 Friedrich Wilhelm Bessel (1784–1846), German astronomer, completes the first distance measurement of an object outside the solar system, the dwarf star 61 Cygni, using the trigonometric parallax technique. After careful observations with an instrument of his own design, called a heliometer, he determines that the star 61 Cygni is some 6 light years away (35,000,000,000,000 miles). This is the first calculation of the distance of a star. Bessel's achievement is, like Bradley's aberration of light, visible evidence that Earth itself moves through space. It also shifts astronomers' attention away from the solar system to the outer universe of stars.

1838 Gerardus Johannas Mulders (1802–1880), Dutch chemist, coins the word "protein."

1838 Isaac Ray (1807–1881), American physician, writes the first book on the medical jurisprudence of insanity. In this work he describes a form of insanity that he says impairs the moral sense and makes a person less responsible for his actions. It becomes known as "Ray's mania."

1838 Jan Evangelista Purkinje (1787–1869), Czech physiologist, first describes a large group of specific cells in the cerebellum, now known as "Purkinje cells."

1838 Justus von Liebig (1803–1873), German chemist, makes a general definition of a radical. In a paper published this year on common radicals, he points out the usefulness to organic chemistry of many methods developed by inorganic chemists.

1838 Martin Heinrich Rathke (1793–1860), German anatomist, describes the formation of the pituitary gland.

1838 Matthias Jakob Schleiden (1804–1881), German botanist, writes an article in which he applies the emerging cell theory to plants, which he describes as a community of cells. He continues the ideas of Robert Brown and influences Theodor Schwann to extend the theory further.

1839 Johann Karl Friedrich Gauss (1777–1855), German mathematician, publishes his *Allgemeine Theorie der Erdmagnetismus*; its mathematical treatment allows for the expression of the magnetic potential at any point on Earth's surface.

1839 Michael Faraday (1791–1867), English physicist and chemist, publishes the first of his three-volume work *Experimental Researches in Electricity.* These volumes contain all of his electrical papers to the Royal Society for a span of 25 years.

1839 William Robert Grove (1811–1896), British physicist, devises an improved electric cell that uses hydrogen and oxygen.

1839 Adam Sedgwick (1785–1873) and Roderick I. Murchison (1792– 1871), English geologists, chose the term "Devonian" to distinguish the rocks of the Paleozoic era between the Silurian and the Carboniferous time.

1839 An astronomical observatory is built at Pulkovo, Russia. Organized and led by Friedrich Georg Wilhelm von Struve (1793–1864), its modern instruments make it the world capital of astronomy. During World War II it is completely destroyed by the invading German army. It has since been rebuilt.

1839 Carl Gustav Mosander (1797–1858), Swedish chemist, discovers a new element, lanthanum, which he names after a Greek word meaning "hidden." Mosander's work reveals the complexity of the rare earth minerals.

1839 Caspar Wistar Pennock (1799–1867) of the United States invents the first flexible-tube stethoscope. This replaces the awkward wooden tube invented by Rene Laennec (1781–1826) and improves diagnoses.

1839 Charles Lyell (1797–1875), Scottish geologist, first identifies the Pleistocene Period in the history of Earth.

1839 First dental school in the United States and in the world, the Baltimore College of Dental Surgery, is founded by Chapin Aaron Harris (1806–1860).

1839 Harvard College Observatory is founded, becoming the first official observatory in the United States. With William Cranch Bond (1789–1859) as its first director, it obtains a 15-in (38-cm) refractor telescope in 1847.

1839 Jan Evangelista Purkinje (1787–1869), Czech physiologist, coins the term "protoplasm" for cellular matter.

1839 Roderick Impey Murchison (1792–1871), Scottish geologist, publishes his 800-page work *The Silurian System*. It gives order and a new name to the older rocks found below those that William Smith (1769–1839) had already ordered and establishes for the first time the stratigraphic sequence of early Paleozoic rocks. This enables geologists to accurately trace Earth's history backward across an increasingly long span of time.

1839 Theodor Schwann (1810–1882), German physiologist, extends the theory of cells from plants to animals. He states in his book *Mikroscopische Untersuchungen*... that all living things are made up of cells, each of which contains certain essential components. He also coins the term "metabolism" to describe the overall chemical changes that take place in living tissue.

1839 Thomas Henderson (1798–1844), Scottish astronomer, announces his measurement of the parallax of the star system called Alpha Centauri. He places this unusually bright star at just over four light years away, making it the closest system known to this day. Although he accomplished this in 1832, he waits until this year to announce.

1839 William Hallowes Miller (1801–1880), English mineralogist, publishes *A Treatise on Crystallography*, in which he introduces the "Millerian indices" for crystals. This is a system of indexing that uses three numbers to describe each different type of crystal face.

1839 William Robert Grove (1811–1896), English physicist, constructs the first fuel cell using hydrogen and oxygen.

1839 First dental journal, *American Journal of Dental Science*, makes its appearance in New York.

1840 Alexandre Edmond Becquerel (1820–1891), French physicist, discovers the photovoltaic effect as he demonstrates that when light induces certain chemical reactions it can produce an electric current. This leads him to invent a device that can measure light intensity by determining the intensity of the current produced.

1840 Jean Charles Atahnase Peltier (1785–1845), French physicist, introduces the concept of electrostatic induction. This is a method of charging a conductor by closely juxtaposing another charged object to attract all charges of one sign and then grounding the conductor to bleed off the other group of charges, leaving a net charge behind.

1840 Christian Friedrich Schönbein (1799–1868), German-Swiss chemist, discovers ozone. Having studied the peculiar odor that surrounds electrical equipment, he finds that he can reproduce it by electrolyzing water or by allowing phosphorous to oxidize. He names it after the Greek word for "smell."

1840 First national report of public health statistics (U.S.) is *Statistical Report on Sickness and Mortality in the Army of the United States, 1819–1839* by Samuel Forry (1811–1844).

1840 First textbook of nervous diseases is written by Moritz Heinrich Romberg (1795–1873) in Germany. In 1853 it appears in English in two volumes as *A Manual of the Nervous Diseases of Man*.

1840 Germain-Henri Hess (1802–1850), Swiss-Russian chemist, formulates the law that

states that the quantity of heat evolved in a chemical change is the same no matter what chemical route the reaction takes (through a single stage or through many stages). This became known as "Hess's law" and made Hess the founder of thermochemistry.

1840 Jöns Jakob Berzelius (1779–1848), Swedish chemist, first introduces the name "allotropy" to describe the existence of different varieties of an element. He converts charcoal into graphite and declares that the same element may have different forms.

1840 Jean Louis Rodolphe Agassiz (1807–1873), Swiss-American geologist, publishes his *Etudes sur les Glaciers*, in which he first puts forth his theory of the Ice Age and the movement of glaciers. His ideas would not be accepted for another twenty-five years.

1840 Johann Karl Friedrich Gauss (1777–1855), German mathematician, publishes his *Allgemeine Theorie des Erdmagnetismus*, in which he is able to determine, via his mathematical calculations, the magnetic potential at any point on Earth's surface.

1840 John James Audubon (1785–1851), French-American ornithologist, publishes the first volume of his *Birds of America* (1840–1844). This illustrated work is considered among the most beautiful natural history studies ever done. Although Audubon usually painted from dead specimens, he is regarded as one of the first American conservationists.

1840 John William Draper (1811–1882), English-American chemist, pioneers photochemistry with his recognition that light brings about chemical reactions through absorption by the molecules of light energy.

1840 Justus von Liebig (1803–1873), German chemist, publishes his *Die Organische Chemie in ihrer Anwendung auf Agrikultur und Physiologie*, in which he shows that plants synthesize organic compounds from carbon dioxide in the air, but take their nitrogenous compounds from the soil. He also says that ammonia (nitrogen) is needed for plant growth, and introduces the use of mineral fertilizers.

1840 Karl Bogislaus Reichert (1811–1883), German anatomist and embryologist, introduces the cell theory into embryology, showing that egg segments develop into cells and that organs develop from them.

1840 Rudolf Albert von Kölliker (1817–1905), Swiss anatomist and physiologist, proves (while still a student) that spermatozoa and eggs or ova are derived from tissue cells. He also applies the cell theory to embryology and histology.

1840 The British custom of afternoon tea is begun by the Duchess of Bedford.

1840 Wilhelm Gotthelf Lohrmann (1796–1840), German land surveyor, dies before completing his elaborate map of the moon. It is completed and published in 1878 by German astronomer Johann Friedrich Julius Schmidt (1825–1884).

1840 William Bowman (1816–1892), English anatomist, publishes his classic paper "On the Minute Structure and Movement of Voluntary Muscle." This becomes the definitive study of muscle histology (the study of minute tissue structure).

1840 John W. Draper (1811–1882), English-American scientist, takes the first picture of the moon. Using the newly-invented Daguerreotype process, he attaches a telescope to his camera and exposes the plate for a full 20 minutes.

1841 James Prescott Joule (1818–1889), English physicist, publishes a paper in which he affirms the existence of a proportionality between the heat manifested in conductors and the square of the strength of the electrical current flowing through them. This becomes known as the Joule effect.

1841 Carl August Trommer (1806–1879) of Germany first publishes his test for sugar in the urine.

1841 Chemical Society is founded in London. This is the first to be composed of professional (non-student) chemists and to have a continuous existence.

1841 Friedrich Gustav Jacob Henle (1809–1885), German pathologist and anatomist, publishes his *Allegemeine Anatomie*, which

becomes the first systematic textbook of histology (the study of minute tissue structure) and includes the first statement of the germ theory of communicable disease.

1841 Johan Heinrich Maedler (1794–1874), German astronomer, publishes his *Populare Astronomie.* Intended for the layman, this work becomes very popular and goes through six editions in his lifetime.

1841 Roderick I. Murchison (1792–1871), English geologist, separates the Permian period from the Carboniferous.

1842 Christian Johann Doppler (1803–1853), Austrian physicist, discovers the effect on the observed frequency of sound waves that is produced by the motion of the source or the observer as the source moves closer or farther away. The mathematical relationship that relates their pitch to the relative motion of the source or the observer is called the Doppler effect. He predicts that light waves would behave in the same manner.

1842 Julius Robert Mayer (1814–1878), German physicist, produces the first fairly accurate mechanical equivalent of heat. In his statement of the conservation of energy, he is one year ahead of James Prescott Joule (1843) and precedes Hermann von Helmholtz (1847) as well. Circumstances dictate that he gets little credit for either until his later years.

1842 Charles Robert Darwin (1809–1882), English naturalist, publishes *The Structure and Distribution of Coral Reefs*, in which he reiterates the link between the submersion of volcanic islands and the formation of atolls. Also in this year, he writes the first abstract of what will become his theory of natural selection.

1842 Eugène-Melchior Peligot (1811–1890), French chemist, first isolates the metal uranium.

1842 John Bennett Lawes (1814–1900), English agricultural scientist, experiments with artificial fertilizer and develops superphosphate, the first commercial artificial fertilizer. He patents a method for its manufacture (first from animal bones and then from minerals) and sets up a factory.

1842 Justus von Liebig (1803–1873), German chemist, publishes his *Die Organische Chemie in ihrer Anwendung auf Physiologie und Pathologie*, which is the first formal treatise on organic chemistry as applied to physiology and to pathology.

1842 Richard Owen (1804–1892), English zoologist, first coins the word dinosaur ("terrible lizard").

1842 Samuel Forry, Assistant U.S. Surgeon General, publishes *The Climate of the United States and Its Endemic Influences*, which is the first American book on medical climatology.

1842 Theodor Ludwig Wilhelm Bischoff (1807–1882), German embryologist, publishes the first textbook of comparative embryology—*Entwicklungs-geschichte der Saugerthiere und des Menschen.*

1842 The U.S. National Observatory is founded in Washington, D.C.

1842 William Barton Rogers (1804–1882) and his brother, Henry Darwin Rogers (1808–1866), American geologists, notice the wave-like folded tectonic structure of the Appalachian mountains and attribute this to the infusion of molten material from deep underground. They have two other geologist brothers, James and Robert, and are all sons of the Irish emigré Patrick Kerr Rogers (1776–1828) who taught geology at William and Mary in Williamsburg.

1842 William Bowman (1816–1892), English anatomist, first demonstrates that urine is the product of super-filtration by the membrane of the Malpighian bodies of the kidney's cortex.

1842 First use of ether as an anesthetic during a tooth extraction is conducted by American dentist Elijah Pope under the guidance and direction of American medical student William E. Clarke. The operation, the first of its kind, is entirely successful, but Clarke makes no record of it.

1842 Crawford Williamson Long (1815–1878), American physician, successfully and painlessly removes a small cyst from a boy's neck, using ether as an anesthetic. Long

makes no attempt to publicize this accomplishment until 1849.

1842 First attempt to photograph a total solar eclipse is made by the Austrian astronomer Versuch von Majocci. He only obtains a photograph of the partial eclipse.

1843 Charles Wheatstone (1802–1875), English physicist, invents the Wheatstone bridge. This very sensitive instrument measures electrical resistance.

1843 James Prescott Joule (1818–1889), English physicist, publishes his value of the amount of work required to produce a unit of heat, called the mechanical equivalent of heat. The value of the mechanical equivalent of heat is eventually represented by the letter J, and a standard unit of work is now called the joule.

1843 Carl Gustav Mosander (1797–1858), Swedish chemist, discovers the metal erbium.

1843 Charles-Frédéric Gerhardt (1816–1856), French chemist, simplifies chemical formula-writing, so that water becomes H2O instead of the previous H4O2.

1843 Claude Bernard (1813–1878), French physiologist, publishes his first physiological paper. Besides his many discoveries, he contributes a major concept called "milieu intérieur." This states that the complex functions of the body's many organs are intimately related and are all geared toward maintaining some kind of internal equilibrium.

1843 Gabriel Andral (1797–1876), French physician, is the first to urge that blood be examined in cases of disease.

1843 Heinrich Samuel Schwabe (1789–1875), German astronomer, announces the results of seventeen years of observing the sun. He discovers that sunspots wax and wane according to a ten-year cycle. Although they actually have an eleven-year cycle, this discovery is considered to mark the beginning of modern solar studies.

1843 James Hall (1811–1898), American geologist, publishes his *Geology of New York*, which becomes one of the classics of American geology.

1843 John Phillips (1800–1874), English geologist and paleontologist, publishes an article in which he is the first to interpret slaty cleavage as an effect of mechanical strain.

1843 Martin Barry (1802–1855), English physician and physiologist, observes the union of sperm and ovum of rabbits.

1843 Mathew Brady (1823–1896), American photographer, is one of the first students of American artist and inventor Samuel Finley Breese Morse (1791–1872), who teaches Daguerre's photographic process at $50 per student.

1843 Oliver Wendell Holmes (1809–1894), American author and physician, discovers the contagiousness of puerperal fever (childbed fever).

1843 Urbain-Jean-Joseph Leverrier (1811–1877), French astronomer, completes ten years of calculations and shows that the orbital eccentricity of Earth has varied between near zero and six percent over the past 100,000 years.

1843 William Bowman (1816–1892), English anatomist, publishes the first of two volumes titled *The Physiological Anatomy and Physiology of Man*. This is the first work on physiology in which histology (the study of the minute structure of tissues) plays a major role.

1843 William Edmond Logan (1798–1875), British-Canadian geologist and the first director of the Geological Survey of Canada, publishes his research on the geological formations of North America. His work makes him a pioneer in the geology of the Pre-Cambrian period. He is also the first to determine that coal beds are formed in place as well as the first to discover reptile remains of the Carboniferous System (345–280 million years ago).

1843 William Henry Fox Talbot (1800–1877), English inventor, patents a process for making enlargements from his Talbotype negatives.

1843 John Couch Adams (1819–1892), English astronomer, studies the deviations in the orbital path of the planet Uranus and calculates mathematically that there

is another planet nearby that accounts for this anomaly. In 1845 he presents this information to his superiors at the Cambridge Observatory who neglect his work. Only after Urbain-Jean-Joseph Leverrier announces with his colleague Galle the discovery of the planet Neptune in 1846 (using the same method as Adams) does he get a share of the credit

1844 Agostino M. Bassi (1773–1856), Italian physician, asserts that smallpox, bubonic plague, syphilis, and spotted fever are due to living parasites. He becomes the founder of the parasitic theory of infection.

1844 Alexander von Humboldt (1769– 1859), German naturalist, publishes the first of his five-volume work, *Kosmos.* This ambitious project is considered the first reasonably accurate encyclopedia of geography and geology, and many regard it as the founding text of the science of geophysics.

1844 Antoine-Jérôme Balard (1802–1876), French chemist, discovers amyl nitrate. This drug will be used in the treatment of angina pectoris.

1844 First attempt to determine longitude by the instantaneous transmission of the time by the newly-invented telegraph is made between Washington, D.C., and Baltimore, Maryland.

1844 Friedrich Wilhelm August Argelander (1799–1875), German astronomer, is the first to begin a detailed study of variable stars, and his methods of estimating their changing brightness establish this subject as a new branch of astronomy.

1844 Horace Wells (1815–1848), American dentist, is the first to use nitrous oxide as an anesthetic in dentistry.

1844 Karl Karlovich Klaus (1796–1864), Estonian chemist, discovers ruthenium.

1844 Robert Chambers (1802–1871), Scottish publisher, publishes anonymously his *Vestiges of the Natural History of Creation.* This best-selling book offers a sweeping view of evolution, and although incorrect in many specifics, it does pave the way for Darwin's theory by familiarizing the public with evolutionary concepts.

1844 The great auk (*Pinguinis impennis*), a bird of the northern seas, becomes extinct. Although other species of auk are diving birds, the great auk could not fly.

1844 William Thomas Green Morton (1819–1868), American dentist—upon the suggestion of American chemist Charles Thomas Jackson (1805–1880)—successfully fills the tooth of a patient who is anesthetized with chloric ether. Morton then learns from Jackson that sulfuric ether is also an anesthetic, and he soon uses it successfully to extract a deeply-rooted tooth.

1844 Forerunner of the American Psychiatric Association is founded. Called the Association of Medical Superintendents of American Institutions for the Insane, it is established in Philadelphia.

1845 Adolph Wilhelm Hermann Kolbe (1818–1884), German chemist, first synthesizes acetic acid from inorganic materials.

1845 Justus von Liebig (1803–1873), German chemist, begins four years of work on chemical fertilizers; this eventually establishes the premise for what becomes the fertilizer industry.

1845 Karl Theodor Ernst von Siebold (1804–1885), German zoologist, recognizes that protozoa are single-celled organisms and is the first to describe them as organisms in themselves.

1845 William Parsons, Earl of Rosse (1800–1867), Irish astronomer, uses a 72-inch telescope of his own construction and becomes the first to detect the spiral shapes of cloudy objects millions of light years away that are much later recognized as independent galaxies like our own Milky Way. By 1850, he has discovered fourteen of them.

1845 Jean-Bernard-Léon Foucault (1819–1868) and Armand-Hippolyte-Louis Fizeau (1819–1896), both French physicists, successfully photograph sunspots.

1845 The College of Chemistry in London becomes the Royal College of Chemistry.

1846 John James Waterson (1811–1883) publishes a brief excerpt of a work that would have connected heat phenomena to the

principles of mechanics. Titled *On the Physics of Media that are Composed of Free and Perfectly Elastic Molecules in a State of Motion*, this work is rejected by the Royal Society and is not published in full until 1892.

1846 Wilhelm Eduard Weber (1804–1891), German physicist, introduces a logical system of units for electricity and offers a general mathematical law expressing the force between moving charges.

1846 William Robert Grove (1811–1896), British physicist, publishes *On the Correlation of Physical Forces*, in which he makes an early statement of the principle of the conservation of energy.

1846 The American Medical Association establishes a code of ethics for physicians that declares their obligation to treat victims of epidemic diseases even at a risk to their own lives.

1846 Arthur Hill Hassall (1817–1894) publishes his book *The Microscopic Anatomy of the Human Body*, which is the first textbook in English on this subject.

1846 Ascanio Sobrero (1812–1888), Italian chemist, slowly adds glycerin to a mixture of nitric and sulfuric acids and first produces nitroglycerine. He is so impressed by the explosive potential of a single drop in a heated test tube and so fearful of its use in war, that he makes no attempt to exploit it. It is another twenty years before Alfred Nobel learns the proper formula.

1846 Claude Bernard (1813–1878), French physiologist, discovers the digestive function of the pancreas.

1846 Edward Forbes (1815–1854), English naturalist, publishes a paper in which he details how most of the plants and animals of his homeland migrated there from the Continent during one of three separate episodes of the glacial epoch. Because of this work, he is considered one of the pioneers of biogeography.

1846 Giovanni Battista Amici (1786–1868), Italian physicist, definitely establishes sexuality in flowering plants.

1846 Hugo von Mohl (1805–1872), German botanist, refines the term "protoplasm" to describe the gelatinous material surrounding a cell's nucleus.

1846 James Marion Sims (1813–1883), American surgeon, invents the vaginal speculum. Sims uses his new tool, which resembles a bent spoon, to correct a displaced uterus of a woman who had fallen from a horse. It soon becomes indispensable for other gynecological operations.

1846 Louis Pasteur (1822–1895), French chemist, discovers molecular asymmetry and demonstrates the existence of isomers, becoming among the earliest to deal with the three-dimensional structure of molecules.

1846 Macedonio Melloni (1798–1854), Italian physicist, uses an improved thermopile to measure the heating effect of moonlight (which is reflected sunlight) from high atop Mount Vesuvius.

1846 Oliver Wendell Holmes (1809–1894), American author and physician, first suggests the use of the terms "anaesthesia" and "anaesthetic" in a letter to William Thomas Green Morton (1819–1868), American dentist.

1846 Robert Mallet (1810–1881), English engineer, publishes an article on the dynamics of earthquakes. During his career, he compiles the first modern catalog of recorded earthquakes and the first seismic map of Earth. He also coins the word seismology.

1846 William Robert Grove (1811–1896), English physicist, offers the first experimental evidence for thermal dissociation. He shows that water (steam) in contact with a strongly heated wire will absorb energy and break up (dissociate) into hydrogen and oxygen.

1846 Urbain-Jean-Joseph Leverrier (1811–1877), French astronomer, discovers a new planet he calls Neptune. It is actually first seen by his colleague, the German astronomer Johann Gottfried Galle (1812–1910). Leverrier suspects that a new planet may exist as he tries to account for the slight orbital deviations of the planet Uranus.

He discovers this new planet solely by pure calculation and then tells Galle where to look in the sky. This is perhaps the most dramatic demonstration of the validity of Newtonian theory.

1846 William Lassell (1799–1880), English astronomer, discovers Triton, Neptune's largest satellite.

1846 Ether is first used in a widely-publicized demonstration in Boston. William Thomas Green Morton (1819–1868), American dentist, persuades American surgeon John Collins Warren (1778– 1856) to conduct a public demonstration of ether use, and Warren successfully removes a small tumor from the neck of an anesthetized patient at Massachusetts General Hospital.

1847 Hermann Ludwig Ferdinand von Helmholtz (1821–1894), German physiologist and physicist, publishes his *Uber die Erhaltung der Kraft*, which is the most detailed and clearest explanation of the concept of conservation of energy.

1847 James Prescott Joule (1818–1889), English physicist, offers his complete treatment of the law of conservation of energy, stating that energy can neither be created out of nothing nor destroyed into nothing. He establishes that the various forms of energy—mechanical, electrical, and heat—are basically the same and can be changed, one into another.

1847 John William Draper (1811–1882), English-American chemist, discovers that at about 525° C, all substances glow a dull red (later called the Draper point), and that with further heating, they eventually turn bright white.

1847 The American Medical Association is founded and holds its first convention the following year.

1847 Claude Bernard (1813–1878), French physiologist, finds that chemicals are generated in the body and goes on to promote the idea of "internal environment."

1847 Friedrich Georg Wilhelm von Struve (1793–1864), German-Russian astronomer, finds evidence for considerable absorption of light in space.

1847 Ignaz Philipp Semmelweis (1818–1865), Hungarian physician, observes correctly that puerperal fever (childbed fever) is directly related to doctors' uncleanliness. He begins a campaign to institute antiseptic measures by doctors, such as simple handwashing.

1847 James Young (1811–1883), Scottish chemist, pioneers "coal oil," when he discovers a petroleum "spring" at a coal mine in Derbyshire. In 1850, he refines it and files a patent for the production of what is called paraffin oil.

1847 John Collins Warren (1778–1856), American surgeon, introduces ether anesthesia for general surgery. It is soon taken up worldwide as an essential part of surgery.

1847 John Frederick William Herschel (1792–1871), English astronomer, publishes his great star map of the southern hemisphere, the results of fourteen years of work. During his long observations, he discovers 2,306 nebulae and 3,347 double stars. He also states his cyclonic theory of sunspots.

1847 A series of yellow fever epidemics sweeps the American Southern states. The epidemics recur every few years for more than 30 years.

1847 Maria Mitchell (1818–1889), American astronomer, discovers a comet, which brings her to the attention of the scientific world. She becomes the first female astronomer in the United States.

1847 James Young Simpson (1811–1870), Scottish obstetrician, introduces the first use of chloroform anesthesia in both labor and delivery.

1848 William Thomson Kelvin (1824–1907), Scottish mathematician and physicist, explores the concept of absolute zero, at which the volume of a gas would be reduced to zero; he explains it by stating that it is not the volume that reaches zero but rather the motion of the gas's molecules that stops. He then proposes a new temperature scale with its zero mark at absolute zero and its degrees equal to those on the centigrade scale. It becomes known

as the Kelvin scale. He also coins the term "thermodynamics."

1848 Achille-Ernest-Oscar-Joseph Delesse (1817–1881), French geologist, publishes an article in which he originates geometric analysis by areal (a region or tract of Earth) measurement.

1848 The American Association for the Advancement of Science is founded.

1848 Armand-Hippolyte-Louis Fizeau (1819–1896), French physicist, studies light coming from a moving source and shows that the lines in a spectrum ought to shift toward the red if the light is receding and toward the violet if it is approaching. He proves experimentally that Doppler was correct about light waves behaving the same as sound waves. This eventually becomes the basis for the twentieth century theory of an expanding universe.

1848 Count Lesczyc-Suminsky discovers the antheridia (male reproductive organs) of ferns.

1848 Emil Du Bois-Reymond (1818–1896), German physiologist, publishes his first volume of *Investigations into Animal Electricity.* He shows that the nerve impulse is accompanied by a change in the electrical condition of the nerve and has a measurable velocity.

1848 The first medical school solely for women is founded. The Women's Medical College of Pennsylvania becomes incorporated as the Female Medical College of Pennsylvania in 1850.

1848 First school for the mentally retarded is founded. The Massachusetts School for the Idiotic opens this year.

1848 Guillaume Benjamin Amand Duchenne (1806–1875), French physician and pioneer in neurology, makes use of electrodiagnosis and electrotherapy.

1848 Hermann von Fehling (1812–1885), German chemist, invents a solution that provides a test for sugar in urine.

1848 Joseph Henry (1797–1878), American physicist, projects the image of the sun on a white screen, and by sensitive measurements of heat, demonstrates that sunspots are cooler than the rest of the sun.

1848 Julius Robert Mayer (1814–1878), German physicist, argues that solar energy is the source of all energy on Earth. Unaware of the process of fusion (not discovered until the twentieth century), Mayer argues that the sun is slowly contracting and that it will cool down in about 5,000 years.

1848 Karl Theodor Ernst von Siebold (1804–1885), German zoologist, publishes his *Lehrbuch der Verwandtschafts-Verhöltnisse der Wirbellosen Thiere*, which becomes one of the first major texts on comparative anatomy of invertebrates.

1848 John Russell Hind (1823–1895), English astronomer, discovers a new star or nova in the Ophiuchus constellation.

1848 William Lassell (1799–1880), English astronomer, discovers an eighth satellite of Saturn, later named Hyperion. It is also discovered simultaneously by the American astronomer George Phillips Bond (1825–1865).

1849 Evidence defining a solar sunspot cycle of 11 years is published.

1849 Armand-Hippolyte-Louis Fizeau (1819–1896), French physicist, devises his own experiment and accurately measures the speed of light in air using a rotating mirror technique. The value he arrives at is within five percent of today's value. Previous to this, all such measurements had been done using astronomical methods.

1849 James Thomson (1822–1892), Irish engineer, predicts that the freezing point of water can be lowered by adding pressure. He also calculates how much the melting point of ice will be lowered by adding pressure.

1849 Arnold Henry Guyot (1807–1884), Swiss-American geologist, publishes *The Earth and Man.* This and several other of his textbooks are standards in U.S. schools for many years. He is known for the undersea volcanic mountains with flat tops that are named after him.

1849 Benjamin Apthorp Gould (1824–1896), American astronomer, founds the first

American astronomical periodical, the *Astronomical Journal.* Its publication continues until it is halted by the American Civil War in 1861.

1849 Charles-Adolphe Wurtz (1817–1884), French chemist, discovers amines as he synthesizes the first organic derivative of ammonia (called ethylamine).

1849 Edouard-Albert Roche (1820–1883), French astronomer, advances the theory that becomes known as Roche's limit. This is the result of his studies of bodies in space that influence one another. He calculates how the gravitational forces of a large body can impose forces on a smaller circling body that could cause the smaller to break up.

1849 Edward Frankland (1825–1899), English chemist, isolates amyl alcohol, which is eventually used as a solvent for resins and other oily materials.

1849 First guano (feces, particularly that of bats and seabirds) to be used as fertilizer is exported by Peru.

1849 First woman to receive a medical degree in the United States is Elizabeth Blackwell (1821–1910). She graduates this year from Geneva College (now a part of Syracuse University) in New York.

1849 James Dwight Dana (1813–1895), American geologist, writes Volume 10 (*Geology of the Pacific*) of the *Narrative of the United States Exploring Expedition During the Years 1838–1842 under the Command of Charles Wilkes.*

1849 Jean-Louis Prévost (1790–1850), Swiss physician, identifies and describes iodine deficiency goiter.

1849 Johann von Lamont (1805–1879), Scottish-German astronomer, publishes his *Handbuch des Erdmagnetismus*, in which he offers his pioneering research in terrestrial magnetism. His theories are based on the assumption that Earth has a solid magnetic core. He also discovers a regular cycle of magnetic intensity that corresponds roughly with the sun's sunspot cycle.

1849 John Snow (1813–1858), English physician, first states the theory that cholera is a water-borne disease, and that it is usually contracted by drinking. During a cholera epidemic in London in 1854, Snow breaks the handle of the Broad Street Pump, thereby shutting down what he considered to be the main public source of the epidemic.

1849 Karl Friedrich Naumann (1797–1873), German mineralogist, publishes his *Lehrbuch der Geognosie*, in which he is the first to use the word "petrography" in the sense of describing and systematically classifying rocks.

1849 Karl Friedrich von Görtner (1772–1850) of Germany publishes the first comprehensive treatment of hybridization. It will be closely studied by Darwin and will influence Mendel.

1849 Rudolf Wagner (1805–1864), German anatomist and physiologist, and Karl Georg Friedrich Rudolf Leuckart (1822–1898), German zoologist, state that spermatozoa are a definite and essential part of the semen, and that the liquid merely keeps them in suspension. They also show that spermatozoa are not parasites and are essential for fertilization.

1849 Thomas Addison (1793–1860), English physician, describes pernicious anemia and is the first to give an accurate description of the hormone deficiency disease that results from the deterioration of the adrenal cortex. It comes to be known as "Addison's disease."

1850 Claude Bernard (1813–1878), French physiologist, begins work that shows the glycogenic function of the liver. He also estimates quantitatively the sugar in the blood.

1850 Claude Bernard (1813–1878), French physiologist, shows the role of curare in paralyzing muscles.

1850 Guillaume Benjamin Amand Duchenne (1806–1875), French physician and neurologist, gives the first description of the progressive muscular atrophy called locomotor ataxia.

1850 Henry Ingersoll Bowditch (1808–1892), American physician, first introduces the

thoracentesis procedure. His instrument, which is designed to remove fluid from the chest cavity, consists of a needle, some tubing, and a suction pump.

1850 Hermann Ludwig Ferdinand von Helmholtz (1821–1894), German physiologist and physicist, establishes the speed of a nerve impulse (90 f.p.s.)

1850 Ludwig Wilhelmy (1812–1864) of Germany constructs one of the first mathematical equations for describing a chemical process when he offers $dz/dt = -kz$ to describe the hydrolysis of sugar.

1850 Morrill Wyman (1812–1903), American physician, performs the first successful operation in the treatment of pleurisy in the United States.

1850 Norman Robert Pogson (1829–1891), English astronomer, points out that the average first-magnitude star is about 100 times as bright as an average sixth-magnitude star. He then suggests an equation or mathematical ratio that eventually makes it possible to assign value to the nearest tenth or sometimes hundredth.

1850 Rudolf Alber von Kolliker (1817–1905), Swiss anatomist and physiologist, publishes his *Mikroskopische Anatomei*, with its emphasis on cell structure and the importance of the nucleus. This sets the stage for the emergence of the science of cytology.

1850 Theodor Maximillian Bilharz (1825–1862), German physician, discovers the blood fluke and dwarf tapeworm in Egypt. The fluke causes schistosomiasis or "Bilharziasis."

1850 Thomas Graham (1805–1869), Scottish physical chemist, studies diffusion and first distinguishes between crystalloids and colloids. He becomes the founder of colloidal chemistry.

1850 Rudolph Julius Emanuel Clausius (1822–1888), German physicist, publishes a paper that contains what comes to be known as the second law of thermodynamics, stating that, "Heat cannot, of itself, pass from a colder to a hotter body." He later refines the concept.

1850 William John Macquaorn Rankine (1820–1872), Scottish engineer, reads a paper before the Royal Society of Edinburgh in which he declares heat to consist in the rotational motion of molecules. His writing makes the more difficult aspects of thermodynamics understandable to the practicing engineer.

1850 Jean-Bernard-Léon Foucault (1819–1868), French physicist, conducts experiments on the velocity of light and determines that light travels faster in air than in water. The value he obtains for the speed of light is within one percent of the true figure.

1850 William Cranch Bond (1789–1859), American astronomer, photographs the bright star Vega—the first star to be photographed. Bond also photographs the moon the following year, and the image becomes a sensation at the Great Exhibition at the Crystal Palace in London.

1850 William Cranch Bond (1789–1859), American astronomer, discovers the "dusky ring" of Saturn. He finds that it extends about halfway between the inner brighter one and the globe of Saturn.

1851 Armand-Hippolyte-Louis Fizeau (1819–1896), French physicist, measures the speed of light as it flows with a stream of water and as it goes against the stream. He finds that the velocity of light is higher in the former.

1851 Jean-Bernard-Léon Foucault (1819–1868), French physicist, conducts his spectacular series of experiments associated with the pendulum. He swings a heavy iron ball from a wire more than 200 feet long and demonstrates that Earth rotates on its axis. This is demonstrated by the swinging pendulum, which maintains its plane while Earth slowly twists under it. The crowds of spectators who witness this demonstration come to realize that they are watching Earth rotate under the pendulum—experimental proof of a moving Earth.

1851 Henry Clifton Sorby (1826–1908), English geologist and chemist, gives the first description of the microscopical structure of rocks he has cut into thin sections.

1851 Hermann von Helmholtz (1821–1894), German physiologist and physicist, perfects the first ophthalmoscope. This new instrument, which allows the physician to see into the eye, makes ophthalmology an exact science.

1851 Jean-Baptiste-Joseph-Dieudonné Boussingault (1802–1887), French agricultural chemist, begins experiments that show that plants cannot use atmospheric hydrogen. He also demonstrates that plants do not absorb nitrogen from the air but from the soil, in the form of nitrates.

1851 Johann von Lamont (1805–1879), Scottish-German astronomer, discovers the variation in Earth's magnetic field. This leads to his later discoveries.

1851 Wilhelm Friedrich Hofmeister (1824–1877), German botanist, erases the distinction between flowering and non-flowering plants, demonstrating the alternation of sexual and non-sexual generations.

1851 William W. Reid, American physician, first lays down the principles for the reduction of dislocations by simple manipulation. Prior to this, dislocations were reduced or joints were put back into place with weights and pulleys. Reid's methods are simple and are adopted around the world almost immediately.

1851 Hugo von Mohl (1805–1872) publishes his *Basic Outline of the Anatomy and Physiology of the Plant Cell*, in which he proposes that new cells are created by cell division.

1851 William Thomson Kelvin (1824–1907), Scottish mathematician and physicist, publishes *On the Dynamical Theory of Heat*, in which he explores Carnot's work and deduces that all energy tends to run down and dissipate itself as heat. This is another form of the second law of thermodynamics and is advanced further by Rudolf Julius Emmanuel Clausius (1822–1888) about the same time. Kelvin's work is considered the first nineteenth century treatise on thermodynamics.

1851 German astronomer Berkowski (his first name was never published) takes the first successful photograph of a total eclipse. His photograph shows the sun's corona and prominences.

1851 William Lassell (1779–1880), English astronomer, discovers two satellites of Uranus. He names them Ariel and Umbriel.

1852 George Gabriel Stokes (1819–1903), British mathematician and physicist, works with fluorescence (a word he coins) and uses it to study ultraviolet light. He is the first to show that quartz is transparent to ultraviolet light, whereas ordinary glass is not. He also suggests his law of viscosity, which describes the motion of a solid sphere in a fluid as well as Stokes' theorem on vector analysis.

1852 Jean-Bernard-Léon Foucault (1819–1868), French physicist, learns from his pendulum experiment and invents the gyroscope. He sets a wheel within a heavy rim in rotation and sees that when tipped, it is set right again by the force of gravity.

1852 Abraham Gesner (1797–1864), English physician, prepares the first kerosene from petroleum. He obtains the liquid kerosene by the dry distillation of asphalt rock, treats it further, and calls the oil kerosene after the Greek word "keros" for oil.

1852 Alexander William Williamson (1824–1904), English chemist, publishes his study that shows for the first time that catalytic action clearly involves and is explained by the formation of an intermediate compound.

1852 The American Pharmaceutical Association is founded.

1852 Edward Sabine (1788–1883), English physicist, first demonstrates that the frequency of disturbances in Earth's magnetic field parallels the rise and fall of the sunspot cycle of the sun. This also provides the first demonstrative Sun-Earth link that is not related to either the sun's radiation of light or its gravitation.

1852 Felix Dujardin (1801–1860), French zoologist, pioneers microphotography and doubles the power of the microscope by adding a system of prisms and lenses. His new microscope becomes the prototype for all modern light condensers.

1852 François-Rémy-Lucien Corvisart (1811–1882), French physician, introduces the word "tétanie"—to describe the contractions experienced in the disease we now call tetanus—in his doctor's thesis.

1852 James Prescott Joule (1818–1889) and William Thomson (Lord Kelvin; [1824–1907]), both British physicists, show that when a gas is allowed to expand freely, its temperature drops slightly. This becomes known as the Joule-Thomson effect, and it is evidence that molecules of gases have a slight attraction for other molecules. Overcoming this attraction uses energy and causes a drop in temperature.

1852 Karl F.W. Ludwig (1816–1895), German physiologist, begins studies of the heartbeat and muscular activity with his invention called the kymograph. With this rotating drum he is able to record graphically the variations in arterial blood pressure. He also is the first to keep animals alive "in vitro."

1852 Rudolf Wolf (1816–1893), Swiss astronomer, refines the cyclical activity of the sun to a more accurate period of 11.1 years

1852 Mount Sinai Hospital, the first Jewish hospital in the United States, is founded in New York City.

1852 Edward Frankland (1825–1899), English chemist, announces the theory of valence, in which he states that each type of atom has a fixed capacity for combining with other atoms. This concept will lead eventually to Dmitri Ivanovich Mendeleyev's periodic table.

1853 Johann Wilhelm Hittorf (1824–1914), German chemist and physicist, offers the notion of the transport number as he suggests that ions in a solution with a current running through it travel at different speeds.

1853 William Holms Chambers Bartlett (1804–1893), American astronomer, publishes his *Elements of Analytical Mechanics*, which is the first mechanics text for technical students written by an American author.

1853 William John Macquorn Rankine (1820–1872), Scottish engineer, introduces into physics the concept of potential energy, also called the energy of position.

1853 Anders Jonas Ångström (1814–1874), Swedish physicist, demonstrates that the rays emitted by an incandescent gas have the same refrangibility (ability to be refracted) as the rays absorbed by the same gas. The gas emits spectral lines of the same wavelength as those it absorbs when cold.

1853 Charles-Gabriel Pravaz (1791–1853), French physician, first publishes his description of a hypodermic syringe. This will open up an entirely new field for the administration of drugs.

1853 First chemical-pharmaceutical company, the Carlo Erba Co., is established in Milan, Italy. The E.R. Squibb Company follows in Brooklyn, New York, in 1858.

1853 Gustave-Adolphe Thuret (1817–1875), French botanist, gives the first account of fertilization in brown algae.

1853 Hans Peter Jorgen Julius Thomsen (1826–1909), Danish chemist, works out a method of manufacturing sodium carbonate from the mineral cryolite. This mineral will soon become important to the production of aluminum.

1853 Henry Enfield Roscoe (1833–1915), English chemist, begins research that lays the foundation for quantitative photochemistry.

1853 Richard Christopher Carrington (1826–1875) begins eight years of sunspot observation, during which he determines that the spots do not rotate in a totally synchronous way with the sun. This shows that they are not fixed to any part of the sun.

1853 Stanislao Cannizzaro (1826–1910), Italian chemist, discovers a method of converting a type of organic compound called an aldehyde into a mixture of an organic acid and an alcohol. It comes to be called the "Cannizzaro reaction."

1854 George Newport (1803–1854), English naturalist and anatomist, performs the first experiment on animal embryos. He notes that the point of sperm entry determines the planes of segmentation of the egg.

1854 Hermann Ludwig Ferdinand von Helmholtz (1821–1894), German physiologist and physicist, speculates on the inevitable "heat death" of the universe, since the continuous passage of heat from warm to cool bodies will result in a uniform, lower temperature.

1854 Hermann Ludwig Ferdinand von Helmholtz (1821–1894), German physiologist and physicist, suggests that the energy radiated from the sun is derived from the mutual gravitation of its parts as a result of shrinkage. This theory holds until disproved in the twentieth century.

1854 Josiah Dwight Whitney (1819–1896), American geologist, publishes a major book on American mineral resources, *Metallic Wealth of the United States.*

1854 Lyon Playfair (1818–1898), English chemist, first proposes the use of incendiary gases and poisonous gases in the Crimean War. His suggestions are not followed.

1854 Richard Owen (1804–1892), English zoologist, prepares the first full-sized reconstruction of dinosaurs for display at the Crystal Palace in London. Although quite inaccurate, these large exhibition models generate enormous interest in dinosaurs that remains unabated until today.

1854 Rudolph Carl Virchow (1821–1902), German pathologist, first names the neuroglia or supportive "glue cells" in the brain.

1854 Florence Nightingale (1823–1910), English nurse, takes charge of a barracks hospital when the Crimean War breaks out. Through dedication and hard work, she goes on to create a female nursing service and a nursing school at St. Thomas' Hospital (1860). Her compassion and commonsense approach to nursing set new standards and create a new era in the history of the sick and wounded.

1855 Heinrich Geissler (1814–1879), German inventor, devises a mercury pump that produces a much better vacuum than old piston pumps. Called Geissler tubes, they make possible a more advanced study of electricity and eventually of the atom. It is with Geissler tubes that the English physicist Joseph John Thomson (1856–1940) discovers the electron.

1855 Albrecht von Graefe (1828–1870), German surgeon, first introduces the operation of iridectomy in the treatment of iritis, iridochoroiditis, and glaucoma. As the creator of modern surgery on the eye and one of the greatest of all eye surgeons, Graefe's eye clinic becomes world famous, and his pupils include nearly all the best ophthalmologists of the nineteenth century.

1855 Alfred Russel Wallace (1823–1913), English naturalist, publishes his paper "On The Law Which Has Regulated the Introduction of New Species." Although this is written before Wallace conceives of the notion of natural selection, it shows him in the process of anticipating Charles Robert Darwin.

1855 Asa Fitch (1809–1878) of the United States issues the first of his famous fourteen reports (1855–1870) on insects in the states.

1855 Bartolomeo Panizza (1785–1867), Italian anatomist, first proves that parts of the cerebral cortex of the brain are essential for vision.

1855 Carl Bernhard von Cotta (1808–1879), German geologist, publishes a book in which he gives the first major synthesis of the theories of ore deposition.

1855 Charles-Adolphe Wurtz (1817–1884), French chemist, develops a method of synthesizing long-chain hydrocarbons by reactions between alkyl halides and metallic sodium. This method is called the Wurtz reaction.

1855 First modern laryngoscope is invented by the Spanish singing teacher Manuel Garcia (1805–1906), who devises this new instrument to examine the throats of his students. He sends a written account of his invention to the Royal Society of London, and the device becomes a permanent part of laryngology within three years.

1855 First State Board of Health in the United States is founded by the State of Louisiana.

1855 First woman dentist is Emmeline R. Jones.

1855 Henri-Etienne Sainte-Claire Deville (1818–1881), French chemist, first produces aluminum in a pure state. He produces the metal in quantity using his original method of heating aluminum chloride with metallic sodium.

1855 Justus von Liebig (1803–1873), German chemist, publishes his *Die Grundsatze der Agrikulturchemie.* This detailed study of chemical fertilizers lays the foundation for agricultural chemistry.

1855 Robert William Bunsen (1811–1899), German chemist, first uses a burner that is perforated at the bottom so that air is drawn in by the gas flow. It burns steadily with little light and no smoke.

1856 *Journal of the Linnaean Society* is first published.

1856 Charles Edouard Brown-Sequard (1817–1894), English physician, proves in animal experiments that the adrenals are essential for the maintenance of life. He also makes numerous discoveries involving the spinal cord that anticipate the discovery of neurotransmitters.

1856 George Phillips Bond (1825–1865), American astronomer, points out that the brighter a star is, the larger the image it makes on a photographic plate. Using this discovery, he shows that estimates of stellar magnitude can be made from photographs.

1856 Hermann von Helmholtz (1821–1894), German physiologist and physicist, publishes the first part of *Handbuch der Physiologischen Optik* (1856–1867). In this work he unites morphology, physics, and physiology into a single conceptual synthesis.

1856 Nathanael Pringsheim (1823–1894), Silesian biologist, publishes detailed studies of algae.

1856 William Henry Perkin (1838–1907), English chemist, produces the first synthetic dye. He accidentally discovers how to produce mauve from the impure aniline in coal tar (while trying to synthesize quinine) and creates a dyestuffs industry while stimulating the development of synthetic organic chemistry.

1857 Abraham Jacobi (1830–1919), American physician, occupies the first chair of children's diseases in the United States at the College of Physicians and Surgeons in New York.

1857 Albrecht von Graefe (1828–1870), German surgeon, first introduces an operation for strabismus (squinting caused by one eyeball being weaker than the other).

1857 Daniel Kirkwood (1814–1895), American astronomer, studies planetoids and proves that the orbits of those known objects are not evenly distributed about an average orbit. He shows that there are regions totally free of planetoids. These empty areas become known as the Kirkwood gap.

1857 Bacteriology is born with the publication of French chemist and microbiologist Louis Pasteur's (1822–1895), observations that lactic acid fermentation is due to a living organism. Also beginning this year and continuing into 1880, he disproves spontaneous generation by showing that organisms are carried in the air; discovers a cure for silk worm disease; uses attenuated viruses for resistance to fowl cholera; and discovers immunization for anthrax and inoculation for rabies.

1857 Peter Andreas Hansen (1795–1874), German astronomer, publishes his lunar tables. Because of this accurate work on the Moon's orbit, he is able to obtain a value for the sun's distance that is fairly close to that now accepted.

1857 Rudolf Julius Emmanuel Clausius (1822–1888), German physicist, offers a new explanation of evaporation in terms of molecules and their velocities. He shows that evaporation produces a loss of energy in the liquid and a decrease in temperature.

1857 Warren de la Rue (1815–1889), British astronomer, takes the first photograph of the moon that is sharp enough to be magnified twenty times. He also takes the first photographs of the stars. This achievement makes astronomers aware of the potential that photography can offer in terms of seeing and documenting more than the real-time observer can observe.

1857 Wilhelm Petters (1824–1889), Czech physician, first demonstrates the presence of acetone in the urine of diabetics.

1857 George Phillips Bond (1825–1865), American astronomer, is the first to photograph a double star and show its two components.

1858 Balfour Stewart (1828–1887), Scottish physicist, experiments with infrared radiation and shows that at each wavelength, the amount of radiation emitted by a body equals the amount it absorbs.

1858 Hermann Ludwig Ferdinand von Helmholtz (1821–1894), German physiologist and physicist, publishes his study on the integrals of hydrodynamic equations that express whirling motion. This becomes the point of departure for new ideas on the structure of matter that eventually replace the old atomistic concepts.

1858 Julius Plucker (1801–1868), German mathematician and physicist, sends an electric current through a vacuum and describes fluorescent effects in detail. He also discovers that the glow shifts position when placed in the field of an electromagnet. This is the early beginning of an awareness of subatomic particles.

1858 Antonio Snider-Pellegrini, American geologist, publishes *La Creation et ses Mysteres Devoiles*, in which he describes the breakup and drifting apart of the Atlantic continents. He says a violent catastrophe separated the Old and New Worlds and offers the fit of the edges of Africa and South America's coasts as evidence.

1858 Archibald Scott Couper (1831–1892), Scottish chemist, introduces the concept of bonds into chemistry, suggesting the dash or dotted line to represent the chemical bond.

1858 Claude Bernard (1813–1878), French physiologist, discovers the vaso-constrictor and vaso-dilator nerves.

1858 Ernst Krackowizer (1821–1875), Austrian-American physician, first demonstrates the vocal cords with a laryngoscope.

1858 Friedrich August Kekulé (1829–1896), German chemist, defines the concept of valency (though does not use this word) and discovers, with Archibald Scott Couper (1831–1892), Scottish chemist, the tetravalent quality of carbon (that carbon has four "affinity units" or a valence of four).

1858 Guillaume Benjamin Amand Duchenne (1806–1875), French physician and neurologist, gives the classic description of tabes dorsalis, a form of muscular dystrophy.

1858 Henry Clifton Sorby (1826–1908), English geologist and chemist, publishes an article titled "On the Microscopical Structure of Crystals." His prolific microscopic studies of thin slices of rock earn him the title "father of microscopical petrography."

1858 Lewis Morris Rutherfurd (1816–1892), American astronomer, develops the first telescope adapted solely for use with a camera. He devises what is really a camera with a telescope serving as the lens and later proceeds to advance the method of measuring stellar positions on photographs.

1858 Mary Anna Elson (1833–1884), German-American physician, is the first Jewish woman to graduate from the Women's Medical College of Philadelphia. She practices in Philadelphia and later in Indiana.

1858 Rudolph Carl Virchow (1821–1902), German pathologist, founds cellular pathology with the publication of his *Die Cellularpathologie* in Berlin. In this major work he declares his doctrine "Omnis cellula e cellula," saying that all disease is disease of the cells.

1858 Warren de la Rue (1815–1889), British astronomer, devises a photoheliograph, which is a telescope adapted particularly for solar photography.

1858 Giovanni Battista Donati (1826–1873), Italian astronomer, discovers a comet that becomes known as Donati's comet. Later this year it develops a long, curved tail and becomes the first comet to be photographed (by Usherwood).

1858 Papers on variation of species, by both Charles Robert Darwin (1809–1882) and Alfred Russel Wallace (1823–1913), are

read to the Linnean Society, London. The two papers, which present the idea of the origin of species through natural selection, are published together in the Society's *Journal.*

1859 Richard C. Carrington and Richard Hodgson publish (independently) the first recorded observation of a "solar flare." Carrington observes a starlike point of light that bursts from the surface of the sun, but actually believes it to be a meteor falling into the sun.

1859 Gaston Plante (1834–1889), French physicist, builds the first electric battery that can be charged after discharge. This "storage battery" has lead plates in sulfuric acid and is essentially what batteries are today.

1859 Gustav Robert Kirchhoff (1824–1887), German physicist, after discovering the relation between emission and absorption spectra, concludes that the ratio of the emissive and absorptive powers of a body at each wavelength is the same for all bodies at the same temperature. This becomes known as Kirchhoff's law.

1859 James Challis (1803–1882), English astronomer, publishes *Mathematical Theory of Attractive Forces*, which is a physico-mechanical discussion of gravitational interaction. He publishes a work on a theory of molecular forces the following year.

1859 Adolph Wilhelm Hermann Kolbe (1818–1884), German chemist, discovers the reaction named after him ("Kolbe reaction"). This new method makes large-scale production of salicylic acid (for aspirin) possible later in the century.

1859 Albert Niemann (1806–1877) of Germany first prepares cocaine by isolating the active principle of *Erythroxylon coca*, known since ancient times as the "divine plant of the Incas."

1859 Charles Robert Darwin (1809–1882), English naturalist, publishes his landmark work *On the Origin of Species by Means of Natural Selection.* This classic of science establishes the mechanism of natural selection of favorable, inherited traits or variations as the mechanism of his theory of evolution. Among the many geological statements in the book is his argument that although the fossil record is incomplete because of the enormous spans of time, there is evidence that an orderly progression has occurred.

1859 Edouard-Albert Roche (1820–1883), French astronomer, analyzes the effect on a comet's envelope of a hypothetical force emanating from the sun and is able to explain the shape of comets many years before the discovery of the actual physical cause.

1859 First zoological station is founded at Concarneau, France.

1859 Friedrich Wilhelm August Argelander (1799–1875), German astronomer, publishes the first volume of his giant work *Bonner Durchmusterung.* This four volume work (1859–1862) locates the positions of 457,848 stars and is the last star map to be compiled without of photographs. It is reprinted as late as 1950.

1859 Hermann Brehmer (1826–1889), German physician, establishes the first successful sanatorium for tuberculosis at Gorbersdorf in Silesia, Germany. It emphasizes exercise, fresh air, hydrotherapy, and rest.

1859 James Clerk Maxwell (1831–1879), Scottish mathematician and physicist, publishes a mathematical essay on Saturn's rings showing that they cannot be solid but must consist of separate particles. He is later proved correct.

1859 James Clerk Maxwell (1831–1879), Scottish mathematician and physicist, studies the rings of Saturn and produces the first extensive mathematical development of the kinetic theory of gases. He shares this discovery of the distribution of molecular speeds in a gas with Ludwig E. Boltzmann (1844–1906), Austrian physicist, who accomplishes the same independently. It has come to be known as the Maxwell-Boltzmann theory of gases.

1859 Living concretions are discovered on a telegraph cable laid in very deep waters. This discovery explodes the widely-held notion that life cannot exist below a depth of 600 meters.

1859 Urbain-Jean-Joseph Leverrier (1811–1877), French astronomer, incorrectly postulates the existence of another planet he calls "Vulcan" between Mercury and the sun. He bases his idea on peculiarities in Mercury's orbit, which are only later explained by Einstein's theory of relativity.

1859 Ernst Wilhelm Tempel (1821–1889), German astronomer, discovers a small spiral nebula in the Pleiades.

1859 Gustav Robert Kirchhoff (1824–1887), German physicist, announces his discovery of the true nature of the bands of color in the spectrum and begins a new era in astronomy. Together with the German chemist Robert Wilhelm Bunsen (1811–1899), Kirchhoff invents the technique of spectroscopy and uses it to study the composition of the sun. Spectroscopy proves invaluable to astronomy as its understanding of spectral lines serves as a guide to understanding the cosmos itself. The spectroscope marks the birth of astrophysics.

1859 Gustav Robert Kirchhoff (1824–1887), German physicist, uses his newly-developed spectroscopic technique and discovers part of the chemical composition of the sun. His experiments show that when light passes through a gas, the wavelengths that are absorbed are the same as those that the gas would emit when incandescent. He then uses this knowledge to identify half a dozen elements in the sun.

1860 Gustav Robert Kirchhoff (1824–1887), German physicist, introduces the concept of black body and emissivity. A black body is a surface that absorbs all radiation of whatever wavelength falls on it. Such a body would emit all wavelengths if it were heated to incandescence. This concept later becomes important to quantum theory.

1860 James Clerk Maxwell (1831–1879), Scottish mathematician and physicist, publishes a paper in which he offers his kinetic theory of gases. He shows that the motion of molecules is responsible for the production of heat, and that when the average velocity increases, so does the temperature.

1860 Abraham Jacobi (1830–1919), American physician, pioneers the teaching of pediatrics and begins the first bedside medical instruction in the United States.

1860 The first element discovered using the newly-developed spectroscope is cesium. Robert Wilhelm Bunsen (1811–1899), German chemist, and Gustav Robert Kirchoff (1824–1887), German physicist, name their new element cesium after its "sky blue" color in the spectrum.

1860 Frans Cornelius Donders (1818–1889), Dutch surgeon, introduces cylindrical and prismatic eyeglasses to correct astigmatism.

1860 Jakob von Heine (1800–1879), German orthopedist, first describes "infantile spinal paralysis," which becomes known as poliomyelitis (or polio).

1860 Jean-Servais Stas (1813–1891), Belgian chemist, begins work that leads to an accurate method of determining atomic weights. By 1865, he produces the first modern table of atomic weights using oxygen as a standard.

1860 Johann Karl Friedrich Zollner (1834–1882), German astronomer, invents the polarizing photometer. With this instrument astronomers can measure the intensity or brightness and other properties of visible light as well as infrared and ultraviolet radiation.

1860 John Nepomuk Czermak (1828–1873), Czech physiologist, introduces the surgical procedure for rhinoscopy (examination of the nasal passages).

1860 Julius von Sachs (1832–1897), German botanist, first shows that plants can be grown from seed in water only if they are given the necessary chemical nutrients.

1860 Max Johann Sigismund Schultze (1825–1874), German anatomist, first clearly points out the nature of protoplasm, showing that it is approximately the same for all life forms.

1860 Robert Wilhelm Bunsen (1811–1899), German chemist, collaborates with Gustav Robert Kirchhoff (1824–1887), German physicist, and they develop the first

spectroscope. Called the Kirchoff-Bunsen spectroscope, their device refracts light differently and opens up an entire new field of spectrum analysis.

1860 Warren de la Rue (1815–1889), British astronomer, photographs the sun and observes a total eclipse. He is able to show that the "prominences" or spurts of red flame visible around the edge of the moon during an eclipse are from the sun and not the moon. The discovery of these solar prominences in addition to that of the sunspot cycle made two decades earlier is considered the beginning of the science of astrophysics (the study of the constitution of the stars and of the physical processes within them).

1860 Ernst Heinrich Haeckel describes the essential elements of modern zoological classification.

1860 Emmanuel Liais, Brazilian astronomer, discovers a "double comet," which has recently been split apart.

1860 First International Congress of Chemistry is held in Karlsruhe, Germany, and attracts 140 delegates from around the world. Stanislao Cannizzaro (1826–1910), Italian chemist, publishes the forgotten ideas of Italian physicist Amedeo Avogadro (1776–1856)—about the distinction between molecules and atoms—in an attempt to bring some order and agreement on determining atomic weights.

1861 William Thomson Kelvin (1824–1907), Scottish mathematician and physicist, publishes his *Physical Considerations Regarding the Possible Age of the Sun's Heat*, which contains the theme of the "heat death" of the universe. This is offered in light of the principle of dissipation of energy stated in March 1851.

1861 Alexander Mikhailovich Butlerov (1828–1886), Russian chemist, introduces the name "structure" to indicate the mutual bonds between atoms.

1861 Erastus Bradley Wolcott (1804–1880) of the United States first performs a kidney excision as he removes a renal tumor.

1861 Ernest Solvay (1838–1922), Belgian chemist, discovers a practical and inexpensive way of producing sodium bicarbonate. His new method requires much less heat and less fuel. He founds a company in 1863 to begin manufacture, and by 1913 he is producing virtually the entire world supply of sodium bicarbonate.

1861 Ernst Brand (1827–1897), German physician, first introduces "scientific hydropathy" as a treatment for typhoid fever.

1861 Friedrich August Kekulé (1829–1896), German chemist, publishes the first volume of *Lehrbuch der Organischen Chemie*, in which he is the first to define organic chemistry as the study of carbon compounds.

1861 Friedrich Wilhelm Gustav Sporer (1822–1895), German astronomer, announces his discovery of the variation in latitude of sunspot zones over the course of a solar cycle. This comes to be known as Sporer's Law.

1861 George Engelmann (1809–1884), German-American physician and botanist, publishes the first paper on plant pathology in the United States.

1861 Guillaume Benjamin Amand Duchenne (1806–1875), French physician and neurologist, is the first to recognize progressive bulbar palsy, which affects the mouth and larnyx (under the name labioglossolaryngeal paralysis).

1861 Gustav Robert Kirchhoff (1824–1887), German physicist, draws a precise map of the solar spectrum, which the Berlin Academy publishes this year and the next. He uses different color inks with exquisite accuracy, and his complete map is nearly eight feet long. This is a major accomplishment in the knowledge of the physical composition of the universe.

1861 Henry Walter Bates (1825–1892), English naturalist, publishes his classic paper on mimicry (the imitation by a species of other life forms or inanimate objects). His ideas prove supportive of Darwin's ideas of natural selection.

1861 James Clerk Maxwell (1831–1879), Scottish mathematician and physicist, and Thomas Sutton (1819–1875) of England demonstrate the first color reproduction using a photographic process. They

develop the additive three-color process, which later becomes a standard method of color photography.

1861 Julius Homberger, American physician, founds the first journal of ophthalmology in the United States.

1861 Karl Gegenbaur (1826–1903), German anatomist, demonstrates that Theodor Schwann is correct in his statement that all vertebrate eggs are single cells.

1861 Louis Pasteur (1822–1895), French chemist and microbiologist, finally demolishes the theory of spontaneous generation. His ingenious experiment, which allowed air but no dust particles or spores into a flask containing a piece of meat, shows that the meat does not spoil or decay.

1861 Nicolas-Camille Flammarion (1842–1925), French astronomer, publishes *La Pluralité des Mondes Habites* at the age of nineteen. This is the first of some fifty works he writes popularizing astronomy.

1861 Pierre-Paul Broca (1824–1880), French surgeon and anthropologist, first identifies a location in the brain's left cerebral hemisphere that is associated with speech. It is later called "Broca's area."

1861 Robert Wilhelm Bunsen (1811–1895), German chemist, and Gustav Robert Kirchoff (1824–1887), German physicist, discover the metal rubidium, using their new spectroscope.

1861 Rudolph Albert von Kolliker (1817–1905), Swiss anatomist and physiologist, publishes his *Entwicklungsgeschichte des Menschen und der Höheren Thiere*, which is the first treatise on comparative embryology.

1861 William Crookes (1832–1919), English physicist, discovers the element thallium by using the newly-invented tool of spectrum analysis. It is isolated by French chemist Claude August Lamy (1820–1878) the next year.

1862 Adolf Kussmaul (1822–1902), German physician, introduces the clinical use of esophagoscopy.

1862 Anders Jonas Ångström (1814–1874), Swedish physicist, applies the newly-discovered technique of spectroscopy to inspect the solar spectrum and discovers the presence of hydrogen in the sun's atmosphere.

1862 Charles Friedel (1832–1899), French chemist, prepares isopropyl, the first secondary alcohol and one that is later used as a solvent and as rubbing alcohol.

1862 Heinrich Ludwig d'Arrest (1822–1875), German astronomer, discovers the seventy-sixth asteroid, which he names Freia, after a Norse goddess. When Arrest was a student, he made substantive contributions to Johann Gottfried Galle's discovery of Neptune (which Galle did not officially acknowledge until 1877).

1862 Hematoxylin is first introduced. This colorless crystalline compound is extracted from the logwood plant and is used as a biological stain. It turns a deep blue color upon oxidation.

1862 Hermann von Meyer of Germany describes the earliest known fossil bird, called the Archaeopteryx. Found in fine-grained limestone of the Late Jurassic age in Germany, it is about as large as a crow and is very reptile-like.

1862 Johann von Lamont (1805–1879), Scottish-German astronomer, publishes the results of his study of Earth's magnetic field. He determines that its intensity rises and falls in a ten-year period, matching the recently-discovered sunspot cycle. The relation between the two goes unknown for fifty years until the discovery of charged subatomic particles.

1862 Jules Péan (1830–1898), French surgeon, first devises the hemostatic forceps. This pincer-shaped instrument later proves crucial to surgeons who can stop hemorrhages by temporarily closing off an artery.

1862 Julius von Sachs (1832–1897), German botanist, states that sunlight is necessary for photosynthesis. He also proves that starch is a product of photosynthesis and later (1865) finds that chlorophyll is contained in the chloroplasts.

1862 Karl von Voit (1831–1908), German physiologist, and his colleague, Max Joseph von Pettenkofer (1818–1901), German chemist, begin their experiments (1862–1873)

and build a chamber large enough to accommodate a person, thus obtaining the first accurate measurements of gross metabolism.

1862 Viktor von Bruns (1812–1883), German surgeon, performs the first laryngeal operation using a larygoscope.

1862 Alvan Graham Clark (1832–1897), American astronomer, points an 18-inch (45.7 cm) telescope he has just made at the star Sirius and sees that its companion star is not a massive dark object as assumed. Neither Clark nor anyone else knows what to make of this until 1915, when Adams shows it to be what becomes known as a white dwarf.

1862 The U.S. Surgeon General directs the preparation of what becomes a six-volume series titled *Medical and Surgical History of the War of the Rebellion, 1861–1865.* This is the first detailed account of the medical and surgical aspects of an army in battle. The first volume is published in 1875 and the last in 1888.

1863 John Tyndall (1820–1893), Irish physicist, publishes his *Heat as a Mode of Motion*, which is the first popularization of the dynamic theory of heat (heat as molecular vibration).

1863 The *Astronomical Register* is founded and is the first English periodical devoted exclusively to astronomy.

1863 Adolf Johann Friedrich Wilhelm von Baeyer (1835–1917), German chemist, discovers barbituric acid, which becomes the basis for modern sleeping pills.

1863 Albert von Bezold (1836–1868), German physiologist, discovers the accelerator nerve fibers of the heart and shows that their origin is in the spinal cord.

1863 American Veterinary Medical Association is founded.

1863 Casimir Joseph Davaine (1812–1882), French biologist, proves that a specific organism, *Bacillus anthracis*, causes anthrax. After culturing the bacillus, he transmits it from one animal to another.

1863 Cato Maximilian Guldberg (1836–1902), Norwegian chemist and mathematician, and his brother-in-law, Peter Waage (1833–1900), also a Norwegian chemist, publish a paper that formulates the law of mass action. They state that the direction taken by a reaction is dependent not merely on the mass of the various components of the reaction, but upon the concentration or the mass present in a given volume. It is not acknowledged until much later.

1863 Etienne-Jules Marey (1830–1904), French physiologist, invents the sphygmograph, which records both pulse rate and blood pressure.

1863 Ferdinand Reich (1799–1882), German mineralogist, and his assistant, Hieronymus Theodor Richter (1824–1898), examine zinc ore spectroscopically and discover the new, indigo-colored element indium. It is used in the next century in the making of transistors.

1863 Friedrich Wilhelm August Argelander (1799–1875), German astronomer, founds the *Astronomische Gesellschaft*, the first large international organization of astronomers.

1863 James Dwight Dana (1813–1895), American geologist, publishes his *Manual of Geology*, which becomes a standard authority and solidifies his international reputation.

1863 National Academy of Sciences is first incorporated in the United States, with American botanist Asa Gray (1810–1888) as a founding member.

1863 Thomas Huxley (1825–1895), English biologist, extends Charles Darwin's theory of evolution to man in his book *Evidence As To Man's Place in Nature.* He becomes the foremost defender and popularizer of Darwinism.

1863 William Huggins (1824–1910), English astronomer, uses the new science of spectroscopy and studies the spectra of every different kind of object in the heavens. He announces that his spectral studies reveal that the same elements that exist on Earth exist in the stars.

1863 John Alexander Reina Newlands (1837–1898), English chemist, announces his arrangement of the elements in the order of their atomic weights. After discovering that

their properties seem to repeat themselves in each group of seven elements, he calls this the Law of Octaves (after the musical scale). He is the first to do this and is a precursor of Dmitri Ivanovich Mendeleyev (1869).

1863 Astronomische Gesellschaft, an international astronomical society, is founded by 26 astronomers who meet in Heidelberg, Germany. In 1869, this society produces the first great precision star catalog.

1864 Publication of Maxwell's Equations (electromagnetic laws named for James Clerk Maxwell).

1864 William Huggins, English astronomer, makes the first spectroscopic observations of a nova, heralding the start of the era of astronomical spectroscopy.

1864 Alexsander Mikhailovich Butlerov (1828–1886), Russian chemist, prepares butyl alcohol, the first tertiary alcohol. It is later used as a solvent and in synthetic rubber.

1864 Andrea Verga (1811–1895), Italian neurologist, publishes the first post-mortem report in a case of acromegaly (chronic hyperpituitarism marked by enlargement of the feet, face, and hands).

1864 Carl Fromman (1831–1892), German anatomist, introduces the first silver stain for neurons.

1864 Giovanni Battista Donati (1826–1873), Italian astronomer, studies the spectrum of a comet as it nears the sun and discovers that while it is far away it glows from reflected sunlight. As it gets closer however, it heats and begins to glow with a radical change in its spectra. This is the first spectroscopic examination of a comet and marks the beginning of an understanding of the structure of a comet.

1864 The International Red Cross is founded by Jean-Henri Dunant (1828–1910), Swiss humanitarian. It becomes a humanitarian agency with national affiliates in almost every country in the world.

1864 Joseph Janvier Woodward (1833–1884) and Edward Curtis, both of the United States, develop the process of microphotography and publish the first photomicrographs of bacteria.

1864 Louis Pasteur (1822–1895), French chemist and microbiologist, invents the process of slow heating that kills bacteria and other microorganisms. Called pasteurization, it is used first as a way of keeping wine and beer from turning sour.

1864 Pietro Angelo Secchi (1818–1878), Italian astronomer, becomes one of the first to adapt systematically the new science of spectroscopy to astronomy. Over the next four years he makes the first spectroscopic survey of the heavens and studies the spectra of 4,000 stars. He discovers that stellar spectra are different from each other, showing for the first time that there is a difference among stars that is more than just position, brightness, and color. His work lays the foundations for modern spectral classification.

1864 William Thomson Kelvin (1824–1907), Scottish mathematician and physicist, writes on the formation of Earth and the sun and argues that they can be anywhere between 25 to 400 million years old.

1864 William Huggins (1824–1910), English astronomer, shows that bright nebulae such as Orion consist of luminous gas.

1865 Rudolf Julius Emanuel Clausius (1822–188), German physicist, refines the second law of thermodynamics and first introduces the term "entropy," stating that the energy in a closed system will always eventually run down.

1865 Alexander Parkes (1813–1890), English chemist, produces Parkesine (later known as celluloid), the first synthetic plastic material. After working since the 1850s with nitrocellulose, alcohol, camphor, and castor oil, he obtains a material that can be molded under pressure while still warm. Parkes is unsuccessful at marketing his product however, and it is left to the Americans John Wesley Hyatt and his brother Isaiah Hyatt to make it a success as Celluloid.

1865 Armand David (1826–1900), French naturalist, discovers hitherto unknown deer in China.

1865 Claude Bernard (1813–1878), French physiologist, publishes his major work on

experimental physiology titled *Introduction a L'Etude de la Medecine Experimentale.* With this work he founds experimental medicine and pioneers the analytical technique of artificially producing disease.

1865 Francis Galton (1822–1911), English anthropologist, begins his statistical investigations into the inheritance of human characteristics. He is the first to stress the importance of using statistical methods in biology.

1865 Franz Schweigger-Seidel (1834–1871), German physiologist, first proves that a spermatozoon possesses a nucleus and cytoplasm.

c.1865 Jean-Martin Charcot (1825–1893), French physician, distinguishes between neuroses and psychoses and also shows that damage to the brain can cause paralysis and epilepsy.

1865 Johann Joseph Loschmidt (1821–1895), Austrian chemist, is the first to attempt to determine the actual size of atoms and molecules. He uses Amedeo Avogadro's hypothesis to calculate the number of molecules in 22.4 liters of gas.

1865 Joseph Janvier Woodward (1833–1884) of the United States is the first to report the use of aniline dyes for histopathological studies (the microscopic study of diseased tissue).

1865 Jules-Bernard Luys (1828–1897), French physician, describes a nucleus in the hypothalamus, forming a part of the descending pathway from the corpus striatum. It becomes known as the "nucleus of Luys."

1865 Maria Mitchell (1818–1889), American astronomer, is appointed professor of astronomy at the newly founded women's college of Vassar. She is the first female astronomer in the United States and also becomes the first female member of the American Academy of Arts and Sciences.

1865 The work of Otto Deiters (1834–1863) of Germany is published posthumously; it contains the first realistic drawing of a neuron.

1865 Wilhelm Friedrich Hofmeister (1824–1877), German botanist, publishes the first textbook of plant physiology, *Handbuch der Physiologischen Botanik.*

1865 An epidemic of rinderpest kills 500,000 cattle in Great Britain. Government inquiries into the outbreak pave the way for the development of contemporary theories of epidemiology and the germ theory of disease.

1865 Herve Faye (1819–1902) of France offers the first coherent theory on the constitution of the sun. He states that the sun can be considered as a vast heat-radiating machine.

1865 Joseph Lister (1827–1912), English surgeon, uses carbolic acid spray (phenol) during surgery on a compound fracture to prevent infection. Two years later he publishes his paper telling of his successes, and he lays the groundwork for antiseptic surgery.

1866 Adolph Eduard Eberhard Kundt (1839–1894), German physicist, invents a method by which he can make accurate measurements of the speed of sound in the air. He uses a "Kundt's tube" the inside of which is dusted with fine powder that is then disturbed by traveling sound waves.

1866 Charles Lyell (1797–1875), Scottish geologist, publishes the ninth edition of his *Principles of Geology*, in which he accepts and applies Charles Robert Darwin's evolutionary ideas.

1866 Ernst Heinrich Haeckel (1834–1919), German naturalist, states his famous "ontogeny recapitulates phylogeny," saying that the corresponding stages of development are related to evolution. His book, *Generale Morphologie der Organismen*, is published in Berlin.

1866 Ferdinand Zirkel (1838–1912), German geologist, publishes his *Lehrbuch der Petrographie.* It contains an account of Sorby's microscopical approach to studying rocks and is greatly responsible for popularizing this method.

1866 Friedrich August Kekulé (1829–1896), German chemist, propounds his theory of the molecular structure of benzene—a keystone of many important compounds.

1866 Gabriel-Auguste Daubrée (1814–1896), French geologist, suggests that since the

alloy nickel-iron is a common component of many planets' structures, it could be that Earth's core is also formed of that alloy. Today many accept this as correct.

1866 Giovanni Virginio Schiaparelli (1835–1910), Italian astronomer, discovers that falling stars are of cometary origin.

1866 Gregor Johann Mendel (1822–1884), Austrian botanist, discovers the laws of heredity and writes the first of a series of papers on heredity (1866–1869) that formulate the laws of hybridization. His work is disregarded until rediscovered by de Vries in 1900. Unknown to both Charles Robert Darwin and himself, Mendel had discovered the proof that Darwin's theory of evolution required.

1866 Joseph Norman Lockyer (1836–1920), English astronomer, becomes the first to study the spectra of sunspots.

1866 Othniel Charles Marsh (1831–1899), American paleontologist, is appointed professor of vertebrate paleontology at Yale University, the first such professor in the United States. He makes many major fossil discoveries in the western United States and discovers the pterodactyls, the flying lizards of the Creataceous Period.

1866 Pierre-Eugène-Marcelin Berthelot (1827–1907), French chemist, synthesizes acetylene and uses it as a starting point for the synthesis of styrene, benzene, methyl alcohol, ethyl alcohol, and methane.

1866 William Huggins (1824–1910), English astronomer, is the first to study the spectrum of a nova and to show that it is enveloped by hydrogen.

1867 Adolf Kussmaul (1822–1902), German surgeon, first introduces the intubation of the stomach. He washes out the stomach with a stomach-tube for gastric dilation and also uses it to treat gastric ulcers.

1867 Alfred Bernhard Nobel (1833–1896), Swedish inventor, invents dynamite, a safer and more controllable version of nitroglycerin. He combines nitro with "kieselguhr," or earth containing silica and discovers that it can not be exploded without a detonating cap.

1867 Anders Jonas Ångström (1814–1874), Swedish physicist, is the first to study the spectrum of the aurora borealis.

1867 The Canadian Medical Association is founded.

1867 Hans Peter Jörgen Julius Thomsen (1826–1909), Danish chemist, compiles the first tables of the relative strength of acids.

1867 John S. Bobbs (1809–1870), American surgeon, performs the first cholecystotomy—the surgical removal of stones from the gallbladder by an incision in the abdomen.

1867 Maximilian Franz Joseph Wolf (1863–1932), German astronomer, and George-Antoine-Pons Rayet (1839–1906), French astronomer, discover gaseous stars whose steady brightness and high temperatures make them an entirely new class of stars. They come to be known as Wolf-Rayet stars.

1867 Quintino Sella (1827–1884), Italian crystallographer, founds the Comitato Geologico d'Italia to promote that country's geological survey.

1867 Richard Anthony Proctor (1837–1888), English astronomer, offers the first system of names for the topography of the planet Mars. His system is later superseded by that of Schiaparelli.

1867 Robert Koch (1843–1910) establishes the role of bacteria in anthrax, providing the final piece of evidence in support of the germ theory of disease. Koch goes on to formulate postulates that, when fulfilled, confirm bacteria or viruses as the cause of an infection.

1868 Anders Jonas Ångström (1814–1874), Swedish physicist, publishes a map of the solar spectrum in which he accurately identifies about 1,000 absorption lines.

1868 August Friedrich Horstmann (1842–1929), German chemist, founds chemical thermodynamics.

1868 Carl August Wunderlich (1815–1877), German physician, publishes his major work on the relation of animal heat or fever to disease. He is the first to recognize that fever is not itself a disease but is rather a symptom. He insists on accurate records of

a patient's fever, and his writing forms the basis of modern clinical thermometry.

1868 Carl Hermann Wichelhaus (1842–1927), German chemist, introduces the term "valency."

1868 Emilij F. von Wolfring (1832–1906), Polish ophthalmologist, describes the small glands in the subconjunctival tissue in the eyelids. They become known as Wolfring's glands.

1868 Jean-Antoine Villemin (1827–1892), French physician, first demonstrates that the origin of tuberculosis is not spontaneous, but that it is a specific infection caused by a transmitted agent.

1868 Jean-Baptiste Elie de Beaumont (1798–1874), French geologist, establishes the Service Géologique de France in order to promote a geological survey of France.

1868 John Wesley Hyatt (1837–1920), American inventor, searching for an ivory substitute, improves on Parkes's celluloid (known as Parkesine), and patents a method of making billiard balls out of what he names Celluloid. He produces this new plastic material by dissolving pyroxyline and camphor in alcohol and heating the mixture under pressure. He markets it successfully, and his plastics (although very flammable) are used for photographic film, combs, and baby rattles. Research in plastics is greatly stimulated.

1868 Pierre-Jules-César Janssen (1824–1907), French astronomer, studies a total eclipse of the sun and observes an unknown spectral line. He forwards the data to the English astronomer and solar spectral expert Joseph Norman Lockyer (1836–1920).

1868 Joseph Norman Lockyer (1836–1920), English astronomer, studies a newly-noticed line in the spectrum of the sun and concludes that it belongs to a yet unknown element that he names "helium," after the sun. Helium is not discovered on Earth until 1895.

1868 Ludwig Edward Boltzmann (1844–1906), Austrian physicist, publishes a paper in which he independently applies statistics to the kinetic theory of gases and later shares credit with Scottish mathematician and physicist James Clerk Maxwell (1831–1879) for this theory.

1868 Nathanael Pringsheim (1823–1894), Silesian biologist, makes the first scientific studies of algae.

1868 Othniel Charles Marsh (1831–1899), American paleontologist, lays the foundations of American paleontology.

1868 Thomas Moreno y Maiz, French pharmacologist, is credited with being the first to suggest that cocaine be used as a local anesthetic.

1868 Wilhelm Friedrich Hofmeister (1824–1877), German botanist, publishes his *Allegemeine Morphologie der Gewächse*, which becomes the first general work on plant morphogenesis (the study of the formation and differentiation of tissues and organs).

1868 William Henry Perkin (1838–1907), English chemist, synthesizes coumarin from a coal-tar derivative. The production of this pleasant-smelling white, crystalline substance marks the beginning of the synthetic perfume industry.

1868 William Huggins (1824–1910), English astronomer, applies the Fizeau effect or "red shift" idea to the star Sirius and finds a small red shift in one of the hydrogen lines. Using this, he is able to reasonably estimate the velocity at which Sirius is moving away from Earth.

1869 Johann Wilhelm Hittorf (1824–1914), German chemist and physicist, studies cathode tubes and anticipates some of the discoveries of English physicist William Crookes (1832–1919) as he describes the changes that accompany a lowering of gas pressure. He also establishes that their glow is produced by rays originating at the cathode and traveling in straight lines.

1869 John Tyndall (1820–1893), Irish physicist, discovers that a beam of light passing through pure water is not dispersed or interfered with, but when passed through a colloidal solution (one containing tiny particles), the beam is dispersed. This comes to be called the Tyndall effect.

1869 *American Journal of Obstetrics* is founded.

1869 Charles Augustus Young (1834–1908), American astronomer, carefully observes a solar eclipse (and another in 1870) and discovers the "reversing layer" of the sun. These are seen as dark lines in the spectrum that gleam brightly at the moment of totality. He is also the first to photograph the spectrum of the sun's corona.

1869 Dimitri Ivanovich Mendeleyev (1834–1907), Russian chemist, and Julius Lothar Meyer (1830–1895), German chemist, independently put forth the Periodic Table of Elements, which arranges the elements in order of atomic weights. However, Meyer does not publish until 1870, nor does he predict the existence of undiscovered elements as Mendeleyev does.

1869 Francis Galton (1822–1911), English anthropologist, publishes his *Hereditary Genius*, the first sustained scientific investigation of human heredity.

1869 Friedrich von Esmarch (1823–1908), German physician, first introduces the first-aid bandage, a package for use on the battlefield to control hemorrhage.

1869 Johann Friedrich Miescher (1844–1895), Swiss biochemist, discovers nucleic acid (by isolating the nucleus in which deoxyribonucleic acid or DNA will later be found).

1869 Jonathan Homer Lane (1819–1880), American astrophysicist, is the first to investigate mathematically the sun as a gaseous body. His development of the first star model (with the sun and stars as gaseous spheres) marks the birth of theoretical astrophysics.

1869 Mathias Eugene Oscar Liebreich (1838–1908), German physician, first recognizes the hypnotic effect of chloral hydrate. It eventually becomes used as an aid to sleep.

1869 Paul Langerhans (1847–1888), German physician, discovers irregular islands of cells in the pancreas that produce insulin. They become known as the islet cells of the pancreas or the islands of Langerhans.

1869 Simon Schwendener (1829–1919), Swiss biologist, publishes his *Die Algentypen der Flechtengonidien* and states his discovery that lichens consist of algae and fungus that share a symbiotic relationship. This notion of a mutually beneficial relationship is not yet named "symbiosis."

1869 Thomas Andrews (1813–1885), Irish physical chemist, begins work on the liquefaction of gases, during which he discovers their discontinuity below a certain temperature. He suggests that for every gas there is a temperature above which pressure alone will not liquefy it. He called this its critical point.

1869 John Wesley Powell (1834–1902), American geologist, begins an expedition down the canyons of the Green and Colorado Rivers.

1869 William Henry Perkin (1838–1907), English chemist, obtains a patent for the synthesis of the red dye alizarin. He gets the patent one day before the German chemist, Karl J.P. Graebe (1841– 1927). It is Graebe who discovers its molecular structure, but Perkin who first finds a practical way to produce it.

1870 Christian Albert Theodor Billroth (1829–1894), Austrian surgeon, conducts the first extirpation (complete removal) of the larynx. He also is considered the founder of modern abdominal surgery.

1870 Edward Drinker Cope (1840–1897), American paleontologist, begins his lifelong writings about the rich fossil fields of the U.S. West. He discovers the first complete remains of the dinosaurs of the Cretaceous Period and establishes that the Age of Mammals began much earlier than most thought.

1870 Gustav Theodor Fritsch (1838–1927), German anatomist and anthropologist, and Eduard Hitzig (1838–1907), German physiologist and neurologist, discover that electric shocks to one cerebral hemisphere of a dog's brain produce movement on the other side of its body. This is the first clear demonstration of the existence of cerebral localization.

1870 John Hughlings Jackson (1835–1911), British neurologist, studies speech defects and muscle spasms caused by brain damage and epilepsy and gives his name to

"Jacksonian epilepsy," now generally called focal epilepsy. He also believes that the brain's main parts represent an evolutionary succession.

1870 Richard Anthony Proctor (1837–1888), English astronomer, notes the prevalence of "star drift," in which large groups of stars are seen as shifting in the same direction and at the same rate across the sky.

1870 Thomas Huxley (1825–1895) delivers a speech that introduces the terms biogenesis (life from life) and abiogenesis (life from non-life; spontaneous generation). The speech strongly supports Louis Pasteur's claim to have refuted the concept of spontaneous generation.

1871 George Johnstone Stoney (1826–1911), Irish physicist, notices that a simple ratio exists between the wavelengths of three lines in the hydrogen spectrum. In this he anticipates the Swiss mathematician and physicist Johann Jakob Balmer (1825–1898), who offers his formula for this phenomenon in 1885.

1871 Henry Pickering Bowditch (1840–1911), American physiologist, demonstrates the "all-or-nothing" principle of cardiac muscle contraction.

1871 John William Strutt Rayleigh (1842–1919), English physicist, discovers that the degree of scattering of light by very fine particles is a function of the wavelength of light. The equation he offers is a solution to the question of why the sky is blue.

1871 Ludwig Edward Boltzmann (1844–1906), Austrian physicist, begins work on his mathematical treatment of the second law of thermodynamics, interpreting it in terms of the statistics of molecular motions. His work lays the foundations of statistical mechanics.

1871 The Cavendish Laboratory is founded at Cambridge University in England. Its first director is the Scottish mathematician and physicist James Clerk Maxwell (1831–1979). A great deal of the development of modern physics takes place at this laboratory, which is endowed by the family of English chemist and physicist Henry Cavendish (1731–1810).

1871 Carl Friedrich Otto Westphal (1833–1890), German neurologist, first describes and introduces the term agoraphobia as the morbid fear of open spaces. He also introduces the term paranoia.

1871 Charles Robert Darwin (1809–1882), English naturalist, publishes his *The Descent of Man, and Selection in Relation to Sex.* This work extends his theory of evolution by applying it to humans.

1871 Ernest Solvay (1838–1922), Belgian chemist, develops a new process for the manufacture of soda (from ammonia).

1871 First physiological laboratory in the United States is established at Harvard University.

1871 First U.S. city to use a filter on its public water supply is Poughkeepsie, New York. The evidence mounts that much disease is spread by contaminated drinking water.

1871 Olaf Hammarsten (1841–1932) of Sweden discovers the role of fibrinogen in the clotting of blood. He shows that coagulation is accomplished by the splitting up of fibrinogen into fibrin and other substances.

1871 Società degli Spettroscopisti Italiana, the first institution of its kind, is founded by Italian astronomers Pietro Angelo Secchi (1818–1878) and Pietro Tacchini (1838–1905). Its purpose is to coordinate the research on solar phenomena and celestial physics done by observatories around the world. It becomes the present-day Societè Astronomica Italiana.

1872 Ernst Mach (1838–1916), Austrian physicist, publishes his *Dic Geschichtc und die Wurzel des Satzes von der Erhaltung der Arbiet.* In this historico-critical work, he attempts to reduce all natural phenomena to mechanics and argues that all knowledge is but a matter of sensation.

1872 Ferdinand Julius Cohn (1850–1898), German botanist, publishes the first of four papers titled "Untersuchungen Über Bacterien," which mark the beginning of bacteriology as a distinct field. He systematically divides bacteria into genera and species and first uses the term bacillus.

1872 HMS *Challenger* departs for what is the first oceanographic voyage (1872–1876) of

scientific discovery. Researchers on board the ship voyage around the world's oceans to collect water samples, plant and animal specimens, and sea floor deposits.

1872 Henry Draper (1837–1882), American astronomer, builds a 28-inch reflector telescope and photographs the spectrum of the star Vega. This is the first time that a stellar spectrum has been photographed. He later studies the spectrum of the Orion Nebula and shows it to be a cloud of dust and gas lit by starlight. He is the son of John W. Draper, who first photographed the moon.

1872 Morrill Wyman (1812–1903), American physician, publishes his *Autumnal Catarrh*, which gives a description of what is now called "hay fever." He distinguishes it from common catarrh (the common cold), saying it is seasonal and can be relieved by going to a different climate.

1872 William Withey Gull (1816–1890), English physician, gives the first description of arteriosclerotic atrophy of the kidney.

1873 Gabriel Jonas Lippmann (1845–1921), French physicist, invents the capillary electrometer, an instrument for measuring extremely small voltages (as small as one thousandth of a volt). This later becomes useful in some of the early electrocardiograms.

1873 James Clerk Maxwell (1831–1879), Scottish mathematician and physicist, publishes *Treatise on Electricity and Magnetism*, in which he identifies light as an electromagnetic phenomenon. He determines this when he finds his mathematical calculations for the transmission speed of both electromagnetic and electrostatic waves are the same as the known speed of light. This landmark work brings together the three main fields of physics: electricity, magnetism, and light.

1873 Johannes Diderik van der Waals (1837–1923), Dutch physicist, offers an equation for the gas laws that contains terms relating to the volumes of the molecules themselves and the attractive forces between them. It becomes known as the Van der Waals equation.

1873 Alexis Anastay Julien (1840–1919), American geologist, and C.E. Wright publish the first microscopic investigation of rocks in the United States.

1873 Bernhard Christian Gottfried Tollens (1841–1918), German agricultural chemist, makes artificial methane, proving that Dmitri Ivanovich Mendeleyev's table is correct.

1873 Camillo Golgi (1843–1926), Italian histologist, devises a way to stain tissue samples with inorganic dye (silver salts) for the first time. He applies this new method to nerve tissue and is able to see details not visible before.

1873 Edouard-Albert Roche (1820–1883), French astronomer, makes the first rigorous mathematical analysis of Pierre-Simon Laplace's nebular hypothesis and also suggests important additions that make it more self-consistent.

1873 Franz Anton Schneider (1831–1890), German zoologist, first describes cell division in detail. His drawings include both the nucleus and the chromosomal strands.

1873 Johannes Diderik van der Waals (1837–1923), Dutch physicist, offers an equation that provides a molecular explanation as to why there is a critical temperature for a gas above which it can only exist as a gas and below which it can be condensed to a liquid.

1873 Navel oranges that were first introduced into the United States from Brazil in 1870 by William Saunders are planted at Riverside, California, by Jonathan and Eliza C. Tibbetts.

1873 Othmar Zeidler of Germany first synthesizes DDT (dichlorodiphenyltrichloroethane) by the reaction of chloral with chlorobenzene in the presence of sulfuric acid. He is not aware of its insecticidal properties.

1873 Richard Anthony Proctor (1837–1888), English astronomer, is the first to suggest that lunar craters are created by meteoric bombardment.

1873 Walther Flemming (1843–1905), German anatomist, discovers chromosomes and

mitosis and gives the modern interpretation of nuclear division.

1873 William Withey Gull (1816–1890), English physician, describes anorexia nervosa and first names it.

1873 William Withey Gull (1816–1890), English physician, first describes myexedema, a condition in which an adult suffers from a lack of the thyroid's hormone. He names this state "cretinoid," because the sufferer's features are similar to those seen in cretins (a term used at the time for those suffering a congenital condition caused by severe hypothyroidism that leads to physical stunting and mental retardation; now the term is offensive).

1874 Karl Ferdinand Braun (1850–1918), German physicist, discovers crystal rectifiers. These devices convert alternating current into direct current and eventually are used to improve a radio transmitter's range.

1874 Adolf Kussmaul (1822–1902), German physician, explains diabetic coma as due to acetonaemia and describes the labored breathing or air hunger that accompanies that condition. It becomes known as "Kussmaul's respiration."

1874 Carl Wernicke (1848–1905), German neurologist, discovers the area of the brain associated with understanding words. It is later called "Wernicke's area."

1874 Edward Walter Maunder (1851–1928), English astronomer, begins his life's work on sunspots at the Greenwich Observatory, taking daily photographs and overall measurements. His massive accumulation of data over a long period of time results in a real contribution.

1874 Hermann Carl Vogel (1842–1907), German astronomer, publishes his *Untersuchungen Über die Spectra der Planeten*, in which he investigates the spectra of planets in an early attempt to learn about their atmospheres.

1874 Jacobus Henricus Van't Hoff (1852–1911), Dutch physical chemist, and Joseph Achille Le Bel (1847–1930), French chemist, independently discover the theory of the relationship of optical activity to molecular structure. The asymmetric, three-dimensional molecular structure of carbon suggests to each scientist a theory of stereochemistry.

1874 Johann Ludwig Wilhelm Thudichum (1829–1901), German-English chemist, publishes his first paper on brain chemistry.

1874 Wilhelm Philipp Schimper (1808–1880), Alsatian botanist, identifies the Paleocene Period of Earth's history.

1874 William de Wiveleslie Abney (1843–1920), English astronomer, invents a dry photographic emulsion that is superior to the old wet method. He uses it to photograph a transit of Venus across the sun.

1874 Willy Kuhne (1837–1900), German physiologist, discovers the proteolytic enzyme in the pancreas, which he calls trypsin.

1874 Wilhelm August Oscar Hertwig concludes that fertilization in both animals and plants consists of the physical union of the two nuclei contributed by the male and female parents. Hertwig carries out pioneering studies of reproduction of the sea urchin.

1874 During the first transit of Venus to occur since 1769, various expeditions are sent around the world to attempt to discover how long it takes for that planet to cross the face of the sun. Astronomers use photographic techniques for the first time.

1875 Adolph Eduard Eberhard Kundt (1839–1894), German physicist, provides experimental confirmation of the kinetic theory of gases.

1875 A.W. Gerrard, English pharmacist, and Hardy of France first introduce the drug pilocarpine. This alkaloid obtained from the South American jaborandi shrub promotes the flow of saliva and perspiration. It comes to be used in glaucoma and conditions involving the heart.

1875 C.C.A. Leonard Landois (1837–1902), German physiologist, discovers that animal serum will hemolyze human blood or liberate its hemoglobin.

1875 Edouard Adolf Strasburger (1844–1912), German botanist, publishes his *Zellbildung und Zelltheilung*, in which he details

mitosis in plant cells. This work establishes the foundations of cytology as a distinct branch of histology.

1875 Edouard van Beneden (1846–1910), Belgian cytologist, describes division of the nucleus prior to his later chromosomal discoveries.

1875 Eduard Suess (1831–1914), Austrian geologist, publishes *Die Entstehung der Alpen*, in which he states that the Alps were not formed by vertical uplift but rather by many folds in the earth lying atop one another.

1875 First attempt in the United States at an institutional treatment of tuberculosis is a sanatorium opened in Asheville, North Carolina, by a physician named Gleitsmann.

1875 Friedrich Losch, German physician, discovers the causative agent in amebic dysentery and distinguishes it from other forms of dysentery.

c. 1875 Friedrich Otto Fritz Giesel (1852–1927), German chemist, is the first in Germany to produce radium salts commercially. A pioneer in radiology and radiochemistry, he dies from lung cancer caused by radiation.

1875 John Wesley Powell (1834–1902), American geologist, publishes his *Exploration of the Colorado River of the West (1869–1872)*. This work originates and formalizes a number of concepts that become part of the standard working vocabulary of geology.

1875 Paul-Emil-Lecoq de Boisbaudran (1838–1912), French chemist, discovers gallium, an element whose properties were predicted to exist by Dmitri Mendeleyev.

1875 Richard Caton (1842–1926), English physiologist, conducts the first experiments on the electrical response of the brain. He applies electrodes to the surface of a rabbit's brain.

1875 Robert Augustus Chesebrough (1837–1933), American manufacturer, first introduces petrolatum, which becomes known by its product name of Vaseline. This smooth, semisolid blend of mineral oil with waxes crystallized from petroleum becomes useful as a lubricant, carrier, and waterproofing agent in many products.

1875 Robert David Fitzgerald (1830–1892) of Australia publishes the first volume of his *Australian Orchids* (1875–1894), in Sydney. It is the first treatise on Australian orchids.

1875 Silas Weir Mitchell (1829–1914), American neurologist, first introduces "rest cure" for the treatment of nervous diseases. Along with a prolonged stay in bed, it also calls for plentiful food and massage.

1875 Theodor Wilhelm Engelmann (1843–1909), German physiologist, proves experimentally that the heartbeat is myogenic or that it originates in the muscle of the heart itself and not from an external impulse.

1875 Wilhelm Heinrich Erb (1840–1921) and Carl Friedrich Otto Westphal (1833–1890), both German neurologists, independently describe the knee-jerk reflex as a diagnostic method.

1875 William Huggins (1824–1910), English astronomer, devises methods of photographing spectra and discovers that objects that are too faint to be seen by the naked eye are made visible with the cumulative effect of long exposures.

1875 William Pepper (1843–1898), American physician, first describes the abnormal changes in the bone marrow that occur in pernicious anemia.

1876 Eugen Goldstein (1850–1930), German physicist, first applies the name "cathode rays" to the luminescence produced at the cathode in a vacuum tube.

1876 Henry Augustus Rowland (1848–1901), American physicist, establishes for the first time that a moving electric charge or current is accompanied by electrically charged matter in motion (and produces a magnetic field).

1876 James Clerk Maxwell (1831–1879), Scottish mathematician and physicist, publishes his *Matter and Motion*, in which he considers the categories of space and time and states with great prescience that, "All our knowledge, both of time and place, is essentially relative."

1876 Josiah Willard Gibbs (1839–1903), American physicist, publishes the first of a series

of papers in which he deals with the principles of thermodynamics and applies them to the complex processes involved in chemical reactions. He also offers an elaborate equation that becomes known as the "phase rule" and that governs the several phases of matter. His work is complicated, difficult to understand, and multidisciplinary and is not really appreciated until the 1890s.

1876 Adolf Wilhelm Hermann Kolbe (1818–1884), German chemist, accomplishes one of the first syntheses of an organic compound from inorganic substances. His work on the electrolysis of the salts of fatty acids enables him to first isolate salicylic acid, which becomes a building block of aspirin.

1876 Alfred Russel Wallace (1823–1913), English naturalist, publishes his major work, *The Geographical Distribution of Animals*, which establishes zoogeography as a modern area of scientific investigation.

1876 American Chemical Society is founded.

1876 American Dermatological Association is founded.

1876 Asaph Hall (1829–1907), American astronomer, discovers a white spot on Saturn's surface that he uses to discover Saturn's period of rotation (ten and three quarter hours).

1876 Edouard Gerard Balbiani (1825–1899), French biologist, sees the formation of chromosomes.

1876 Edward Charles Pickering (1846–1919), American astronomer, is appointed professor of astronomy at Harvard University. There he advances spectroscopy by devising techniques that enable him to study spectra in large numbers at once instead of one star at a time

1876 Ferdinand Zirkel (1838–1912), German geologist, writes Volume VI of the U.S. geological survey, which becomes the first comprehensive work on the petrography of American rocks.

1876 George Wesson Hawes (1848–1882) of the United States publishes an article that is the first memoir in the United States on the petrography of rocks.

c. 1876 Josiah Willard Gibbs (1839–1903), American physicist, applies the laws of thermodynamics to chemical reactions and develops the modern concepts of "free energy" and "chemical potential" as the driving force behind chemical reactions.

1876 Josiah Willard Gibbs (1839–1903), American physicist, discovers the phase rule. He arrives at an equation that relates the variables (like temperature and pressure) to different phases (solid, liquid, gas). His work helps lay the foundation for chemical thermodynamics and generally for modern physical chemistry. The rule is later put into practical application by Dutch physical chemist Hendrik Willem Bakhuis Roozeboom (1854–1907).

1876 Louis Albery Sayre (1820–1900), American orthopedic surgeon, first introduces the use of a plaster jacket to be worn by patients with spinal deformities (Pott's disease).

1876 Pierre-Jules-César Janssen (1824–1907), French astronomer, begins a series of photographs of the sun's surface that he compiles until 1903. He is one of the pioneers of astronomical photography.

1876 Robert Koch (1843–1910), German bacteriologist, is able to cultivate the anthrax bacteria in culture outside the body. He then studies its life cycle and learns how to defeat it. During the next six years, Koch isolates the tubercle bacillus and discovers the cause of cholera.

1876 The Mineralogical Society of Great Britain and Ireland is established.

1876 Thomas Alva Edison (1847–1931), American inventor, builds his laboratory at Menlo Park, New Jersey. This can be considered the first industrial research laboratory and begins the notion of the modern research team.

1876 Wilhelm August Oscar Hertwig (1849–1922), German embryologist and anatomist, observes the fertilization of a sea urchin egg and establishes that genetic material is contributed to the offspring from both parents. He also shows that fertilization is due to a fusion of sperm with the egg nuclei.

1876 Alexander Graham Bell (1847–1922), Scottish-American inventor, files a patent for his telephone only two hours before American electrician and inventor Elisha Gray (1835–1901) files a patent for a similar device. Bell receives the patent for the telephone. His system turns sound vibrations into a fluctuating electric current which is then reconverted into sound waves identical with the original at the other end of the circuit. After years of litigation between Bell and Gray, the courts decide that Bell is the inventor.

1877 John William Strutt Rayleigh (1842–1919), English physicist, publishes *The Theory of Sound*, which becomes the authoritative work on this subject.

1877 Louis Paul Cailletet (1832–1913), French physicist, is the first to successfully liquefy gases as he combines low temperatures with high pressure.

1877 Giovanni Virginio Schiaparelli (1835–1910), Italian astronomer, studies the planet Mars when it is especially close to Earth and observes straight lines that join in a complicated pattern. He calls these lines "canali"—meaning "channels" in Italian, but which becomes popularly translated as "canals." This contributes to public speculation that there is intelligent life on Mars.

1877 James Mason Crafts (1839–1917), American chemist, and Charles Friedel (1832–1899), French chemist, discover that aluminum chloride is a versatile catalyst for reactions tying together a chain of carbon atoms to a ring of carbon atoms. This becomes known as the Friedel-Crafts reaction.

1877 Karl Harry Ferdinand Rosenbusch (1836–1914), German geologist, publishes his *Mikroskopische Physiographie der Mineralien und Gesteine*, in which he offers his genetic classification of igneous rocks, which he bases on mineralogy as well as chemical composition.

1877 Louis Pasteur (1822–1895), French chemist and microbiologist, first distinguishes between aerobic and anaerobic bacteria.

1877 Louis Paul Cailletet (1832–1913), French physicist, and Raoul-Pierre Pictet (1846–1929), Swiss chemist, independently liquefy the permanent gases. They both produce small quantities of liquid oxygen, nitrogen, and carbon monoxide.

1877 Patrick Manson (1844–1922), Scottish physician, first discovers filara—a kind of parasitic worm—as the cause of the tropical disease elephantiasis. The following year he shows it is transmitted by a mosquito.

1877 Robert Koch (1843–1910), German bacteriologist, describes his new techniques of fixing, staining, and photographing bacteria.

1877 Thomas Crowder Chamberlin (1843–1928), American geologist, publishes the first of his volumes on the *Geology of Wisconsin*. He is one of the first to propose that there was not only one Ice Age but actually several.

1877 Wilhelm Pfeffer (1845–1920), German botanist, publishes *Osmotische Untersuchungen*, in which he pioneers the study of semi-permeable membranes. He is able to measure osmotic pressure and is the first to make reliable molecular measurements.

1877 Wilhelm Friedrich Kühne proposes the term enzyme (meaning "in yeast"). Kühne establishes the critical distinction between enzymes, or "ferments," and the microorganisms that produce them.

1877 Asaph Hall (1829–1907), American astronomer, discovers a tiny satellite of Mars. Five days later he is able to find yet another slightly larger one. He names them Phobos and Deimos.

1878 Adolf Johann Friedrich Wilhelm von Baeyer (1835–1917), German chemist, produces the first synthesized indigo blue dye.

1878 Albert Heim (1849–1937), Swiss geologist, publishes his *Untersuchung über den Mechanismus der Gebirgsbildung*. He is the first genuine European geological artist. His talent lay in his power to describe accurately the most complex geological structures and to then illustrate them in brilliant drawings.

1878 Charles Otis Whitman (1842–1910), American zoologist, publishes his first paper on cell-lineage. His work on the early stages of cell development lays the groundwork for future advances.

1878 International Union of Geological Sciences is founded and holds its first session in Paris. Its purpose is to promote discussion and comparison of results of geological research from various countries.

1878 Jean-Charles Marignac (1817–1894), Swiss chemist, discovers the rare earth element ytterbium.

1878 Johann Friedrich Julius Schmidt (1825–1884), German astronomer, completes Lohrmann's work and publishes the last great lunar map to be based on visual observations (rather than on photographs).

1878 John Wesley Powell (1834–1902), American geologist, publishes his *Report on the Lands of the Arid Regions of the United States*, in which he argues that so-called renewable resources are only such if they are preserved and renewed. This work comes to be regarded as a landmark in conservation literature.

1878 Louis-Marie-Hillaire-Bernigaud de Chardonnet (1839–1924), French chemist, invents rayon. He begins by producing fibers that are made by forcing solutions of nitrocellulose through tiny holes and allowing the solvent to evaporate. The end product causes a sensation, as it resembles silk. Rayon is the first artificial fiber to come into common use.

1878 Paul Bert (1833–1886), French physiologist, publishes his *La Pression Barométrique*, which becomes a classic work on the physiological effects of pressure. He correctly states that it is dissolved nitrogen in the blood that causes the disease known as the "bends."

1878 Robert Koch (1843–1910), German bacteriologist, first publishes his landmark findings on the etiology or cause of traumatic infectious disease. It is these findings that establish the rules for properly identifying the causative agent of a disease. Koch states that the microorganism must be located in a diseased animal, and that after it is cultured or grown, it must then be capable of causing disease in a healthy animal. Finally, the newly-infected animal must yield the same bacteria as those found in the original animal.

1878 The "Great Red Spot" on the planet Jupiter becomes suddenly very striking, and is seen by astronomers as brick red and oval in shape.

1878 Joseph Lister (1827–1912) publishes a paper describing the role of a bacterium he names *Bacterium lactis* in the souring of milk.

1878 Charles-Emanuel Sedillot (1804–1883), French surgeon, introduces the term "microbe." It is accepted by French chemist and microbiologist Louis Pasteur (1822–1895) and becomes a universal term for a pathogenic bacterium.

1879 Edwin Herbert Hall (1855–1938), American physicist, announces his discovery of the phenomenon in which a difference of potential develops across a current-carrying conductor that is placed in a magnetic field. This comes to be known as the Hall effect.

1879 Josef Stefan (1835–1893), Austrian physicist, offers the first quantitative rate for the cooling of hot bodies. Called the Stefan-Boltzmann law (also named for Ludwig Boltzmann), it states that the amount of heat radiated by a surface is proportional to the fourth power of the absolute temperature.

1879 A new astronomical observatory is completed in Potsdam, Germany.

1879 Albert Ludwig Siegmund Neisser (1855–1916), German dermatologist, discovers gonococcus, the pus-producing bacterium that causes gonorrhea.

1879 Charles Lapworth (1842–1920), English geologist, proposes a new classification of Lower Paleozoic rocks. He places the new Ordovician system between the Cambrian system and the Silurian system. It is recognized as an eminently reasonable and practical suggestion and is accepted almost immediately.

1879 Constantin Fahlberg (1850–1910), German chemist, and Ira Remsen (1846–1927), American chemist, first prepare saccharin. Also called benzoic sulfimide, it has an obviously sweet taste.

1879 Edward Charles Pickering (1846–1919), American astronomer, lays the foundations of exact stellar photometry with his invention of the meridian photometer. With this he is able to compare the brightness of any star to that of a standard reference star (Polaris).

1879 The first hearing aid is patented in the United States by R.S. Rhodes. This fan-like device that is held between the teeth and uses the principle of bone conduction is called the "audiophone" and is useful for certain kinds of deafness.

1879 Hermann Fol (1845–1892), Swiss physician and zoologist, is the first to observe a spermatozoon penetrate an egg and demonstrates that only one sperm is needed for fertilization.

1879 John Shaw Billings (1838–1913), American surgeon, and Robert Fletcher (1823–1912) of England issue the first volume of *Index Medicus.* This massive medical bibliography is initially arranged by author and subject and continues today.

1879 Josef Stefan (1835–1893), Austrian physicist, publishes the law that bears his name, showing that total radiation increases as the fourth power of temperature. Since the sun's total radiation is known, it is possible—using his law—to calculate for the first time the sun's total radiance, which is about 6,000° C.

1879 Lars Fredrik Nilson (1840–1899), Swedish chemist, discovers scandium, an element whose properties were predicted to exist by Dmitri Mendeleyev.

1879 Max Nitze (1848–1907), German urologist, invents the cystoscope, which vastly improves bladder surgery. This electrically-lighted instrument also proves useful in making urological diagnoses.

1879 Nicolas-Camille Flammarion (1842–1925), French astronomer, publishes his *Astronomie Populaire.* In this work he argues for the existence of canals (and therefore intelligent life) on Mars and generally suggests that all worlds are inhabited by living beings.

1879 Paul-Emil-Lecoq de Boisbaudran (1838–1912), French chemist, discovers samarium, a pale gray, lustrous metallic element that later is used in alloys that form permanent magnets.

1879 The Geological Survey of the United States of America is established under the direction of American geologist Clarence Rivers King (1842–1901).

1879 Vladimir Markovnikov (1837–1904), Russian chemist, disproves the notion that carbon-based molecules can have only six-atom rings, as he prepares molecules with rings of four carbon atoms. In 1889 he produces seven carbon atoms.

1879 Wilhelm Max Wundt (1832–1920), German psychologist, founds the first institute of psychology at the University of Leipzig. He is an experimental psychologist.

1879 William MacEwen (1848–1924), Scottish surgeon, pioneers successful brain surgery.

1879 Albert Nisser identifies *Neiserria gonorrhoeoe* as the cause of gonorrhea.

1879 Thomas Alva Edison (1847–1931), American inventor, produces the first practical incandescent light bulb. Using a filament of scorched cotton thread, his electric light burns for 40 hours.

c. 1880 Emile Hilaire Amagat (1841–1915), French mathematician and physicist, experiments with the physical changes that gases undergo at high pressure and is able to produce a pressure equal to 3,000 atmospheres (44,000 pounds or 20 metric tons per square inch). This record is not exceeded for some time.

1880 Pierre Curie (1859–1906), French chemist, collaborates with his brother, Jacques (1856–1941), and discovers piezoelectricity in crystals. They create ultrasonic sound waves by applying a rapidly changing electric potential to a quartz crystal.

1880 William Crookes (1832–1919), English physicist, explains why a green glow

is induced when an electric discharge is sent through a vacuum. He proves that the glow caused in his "Crookes tube" is caused by negatively charged particles. He cannot however explain what the particles are.

1880 Albert von Mosetig-Moorhof (1838–1907), Austrian surgeon, first introduces iodine use on surgical dressings.

1880 American Surgical Association is founded.

1880 C.L. Alphonse Laveran (1845–1922) isolates malarial parasites in erythrocytes of infected people and demonstrates that the organism can replicate in the cells. He is awarded the 1907 Nobel Prize in Medicine or Physiology for this work.

c. 1880 Carl Oswald Viktor Engler (1842–1925), German chemist, begins his studies on petroleum. He is the first to state that it is organic in origin, and he can be considered the founder of the study of petroleum.

c. 1880 David Ferrier (1843–1928), Scottish scientist, maps the region of the brain called the motor cortex and discovers the sensory strip.

1880 John Milne (1850–1913), English geologist, invents the modern seismograph. This method works by means of a horizontal pendulum whose movement is recorded on a drum, usually by a pen. He also establishes a chain of seismographic stations around the world, marking the beginning of modern seismology.

1880 Karl Joseph Eberth (1835–1926), German pathologist, discovers and first isolates the typhoid bacillus.

1880 Louis Pasteur (1822–1895), French chemist and microbiologist, first isolates and describes both streptococcus and staphylococcus (both in puerperal septicemia).

1880 Ludwig Rehn (1849–1930), German surgeon, carries out the first thyroidectomy (surgical removal) in exophthalmic goiter.

1880 The Seismological Society of Japan is founded.

c. 1880 Walter Holbrook Gaskell (1847–1914), British physiologist, shows that the sympathetic nervous system is not a separate nervous system. His work lays the histologic foundations of the modern study of the autonomic nervous system.

1880 Louis Pasteur (1822–1895), French chemist and microbiologist, develops a method of weakening a microbial pathogen of chicken and uses the term "attenuated" to describe the weakened microbe.

1880 The first issue of the journal *Science* is published by the American Association for the Advancement of Science.

1880 Henry Draper (1837–1882), American astronomer, becomes the first to photograph a nebula as he obtains a photo of the Orion nebula.

1881 Hermann Ludwig Ferdinand von Helmholtz (1821–1894), German physiologist and physicist, demonstrates that since the electrical charges in atoms are divided into definite integral portions, there must also exist a smallest unit of electricity.

1881 Joseph John Thomson (1856–1940), English physicist, introduces the notion of electromagnetic mass, stating that the mass of an object changes when it is charged with electricity.

1881 An international data center is set up in Kiel, Germany, to gather astronomical information and to dispatch it by telegraph so that significant phenomena can be observed by others around the world before they disappear.

1881 Anton Wolfler (1850–1917) of Bohemia first introduces gastroenterostomy (a surgical linking between the stomach and the bowel usually necessitated by cancer).

1881 Clara Barton (1821–1912) of the United States first organizes the American Red Cross in Washington, D.C.

1881 Edward Emerson Barnard (1857–1923), American astronomer, is the first to discover a comet by using a photographic method.

1881 Louis Pasteur (1822–1895), French chemist and microbiologist, publicly inoculates sheep with an "attenuated culture" of anthrax.

1881 Osmond Fisher (1817–1914), English geologist, publishes his *Physics of the Earth's Crust*, which many regard as the first text-

book in geophysics. He states that Earth's fluid interior was subjected to convection currents rising beneath the oceans and falling beneath the continents. This modern view is mostly ignored.

1881 Samuel Pierpont Langley (1834–1906), American astronomer, invents a bolometer, an instrument for accurately measuring tiny quantities of heat. This can tell differences to a hundred thousandth of a degree by way of the size of the tiny electric currents that are created by the heat in a blackened platinum wire. He uses this to measure solar radiation and extends knowledge of the solar spectrum into the far infrared for the first time. This instrument founds spectrophotometry.

1881 Wilhelm Roux (1850–1924), German zoologist, elaborates on existing mechanical accounts of development, saying that there is a "functional adaptation" in embryology. His work on discovering how organs and tissues are assigned their structural form and function at fertilization makes him a founder of experimental embryology.

1881 Eduard Strasburger (1844–1912) coins the terms cytoplasm and nucleoplasm.

1881 C.L. Alphonse Laveran (1845–1922), French physician and parasitologist, discovers the parasite that causes malarial fever.

1882 Balfour Stewart (1828–1887), Scottish physicist, correctly suggests that the daily variations in Earth's magnetic field might be accounted for by horizontal electric currents in the upper atmosphere.

1882 Carlo Forlanini (1847–1918), Italian physician, first introduces the use of artificial pneumothorax (collapsing the lung) as a means of treating pulmonary tuberculosis.

1882 David Gill (1843–1914), Scottish astronomer, photographs a comet and is so impressed by the number of stars captured in the picture that he becomes convinced of the worth of stellar photography. He proceeds to sweep the heavens photographically.

1882 First chair of neurology is established at La Saltpêtrière Hospital in Paris for Jean-Marie Charcot (1825–1893), French physician.

1882 François-Marie Raoult (1830–1901), French physical chemist, demonstrates that the lowering of the freezing point of a solution of a particular substance is proportional to the concentration of the dissolved substance in molecular terms. Known as Raoult's law, this leads to a valuable method for calculating molecular weights.

1882 Friedrich August Johannes Löffler (1852–1915), German surgeon and bacteriologist, and F. Schulze discover the bacterium causing glanders, a contagious and very destructive disease of animals, especially horses and mules, that can be transferred to humans.

1882 George Miller Sternberg (1838–1915), Surgeon General of the U.S. Army from 1893 to 1902, makes the first microphotograph of the tubercle bacillus.

1882 Elie Mechnikoff (1845–1916), Russian-French bacteriologist and physiologist, begins research that results in his discovery of phagocytosis. He demonstrates that white corpuscles in animal blood flock to the site of any infection and are able to ingest the invading bacteria. He calls them "phagocytes" from the Greek meaning "devouring cells."

1882 John Lubbock Avebury (1834–1913), English biologist, publishes his pioneering work on insect behavior titled *Ants, Bees, and Wasps.* He follows this in 1888 with *On the Senses, Instincts, and Intelligence of Animals.*

1882 Jules Violle (1841–1923), French physicist, designs a method of keeping liquefied gas in that state. He is able to sustain low enough temperatures by the insulating properties of a vacuum.

1882 E.P. Lyon first applies centrifugation to eggs. This technique, which uses rapid spinning to impose high centrifugal forces on whatever is being spun, causes separations of matter on the basis of differences in weight. It becomes an important tool in biochemical research.

1882 Robert Koch (1843–1910), German bacteriologist, discovers and announces his

discovery of the tuberculosis bacillus, proving the existence of pathological agents. He enunciates "Koch's postulates." This method or procedure provides the classic model of how to preserve, document, and study bacteria.

1882 Viktor Meyer (1848–1897), German organic chemist, accidentally discovers thiophene. It is derived from coal tar and resembles benzene.

1882 Walther Flemming (1843–1905), German anatomist, publishes his *Zellsubstanz, Kern und Zelltheilung*, in which he details his observations of the longitudinal division or splitting of chromosomes in animal cells. He is the first to observe this phenomenon.

1882 The last transit of Venus until the year 2004 occurs.

1883 Ernst Mach (1838–1916), Austrian physicist, publishes his *Die Mechanik in ihrer Entwickelung Historisch-Kritisch Dargestellt*, in which he offers a radical philosophy of science that calls into question the reality of such Newtonian ideas as space, time, and motion. His work influences Einstein and prepares the way for relativity.

1883 George Francis Fitzgerald (1851–1901), Irish physicist, first suggests a method of producing radio waves. From his studies of radiation, he concludes that an oscillating current would produce electromagnetic waves. This is later verified experimentally by Hertz in 1888 and used in the development of wireless telegraphy.

1883 Thomas Alva Edison (1847–1931), American inventor, discovers the emission of electrons from hot bodies. He inserts a small metal plate near the filament of a light bulb and finds that the plate draws a current when he connects it to the positive terminal of the light bulb circuit, even though the plate is not touching the filament. Called the Edison effect, this is later a major factor in the invention of the vacuum tube.

1883 *Journal of the American Medical Association* is first published.

1883 Andrew A. Common (1841–1903), English amateur astronomer, takes the first really successful direct photographs of a nebula (Orion). He goes on to take some of the finest astronomical photographs of his time.

1883 August F. Weismann (1834–1914), German biologist, begins work that culminates in his germplasm theory (1883–1889). This notion is a precursor of today's knowledge of DNA, for it offers the idea that all living things contain their own special hereditary substance.

1883 August F. Weismann (1834–1914), German biologist, predicts the central features of the mechanism of inheritance.

1883 Eduard Suess (1831–1914), Austrian geologist, publishes his *Antlitz der Erde*, in which he discusses the ancient changes in the continents and seas necessary to form the modern "face of Earth."

1883 Frank Wigglesworth Clarke (1847–1931), American chemist and geophysicist, is appointed as chief chemist to the U.S. Geological Survey. In this position he begins an extensive program of rock-analysis and is one of the founders of geochemistry.

1883 Giulio Bizzozero (1846–1901), Italian pathologist, demonstrates that platelets are a constant element of blood.

1883 Johann Gustav Kjeldahl (1849–1900), Danish chemist, first devises a method for determining the amount of nitrogen in an organic compound. This simple, fast method, which uses concentrated sulfuric acid, becomes known as "Kjeldahl's method."

1883 Paul Gerson Unna (1850–1929), German physician, first introduces the drug ichthyol to treat skin disorders.

1883 Wilhelm Roux (1850–1924), German zoologist, postulates that chromosomes in the nucleus are bearers of hereditary determiners.

1883 Edward Theodore Klebs and Frederich Löffler independently discover *Corynebacterium diphtheriae*, the bacterium that causes diphtheria. It is now sometimes called the Klebs-Löffler bacillus.

1883 Zygmunt Florenty von Wroblewski (1845–1888), Polish physicist, and Karol Stanislaw

Olszewski (1846–1915), Polish chemist and physicist, announce their development of a method of making liquid oxygen in usable quantities. They also liquefy nitrogen and carbon monoxide and are the first to obtain at least a fine mist of liquid hydrogen.

1883 The first of a series of violent explosions occurs on the insular volcano of Krakatoa. The ensuing eruption on this Indonesian island is one of the most catastrophic in history. Explosions on the 27th are heard 2,200 miles away in Australia and propel ash to a height of 50 miles (80.5 km). A series of tsunamis or tidal waves are triggered, the greatest of which is 120 feet (36.6 m) high and kills some 36,000 people in the coastal towns of Java and Sumatra. All life on what remains of Krakatoa is buried under a thick layer of sterile ash, and plant and animal life is not reestablished for five years.

1884 Arthur Nicolaier (1862–1942), German physician, discovers and describes the bacterium that causes tetanus, *Clostridium tetani.*

1884 Bunjiro Koto (1856–1935), Japanese geologist, publishes an article in which he makes the first microscopic study of Japanese rocks.

1884 Edward Charles Pickering (1846–1919), American astronomer, publishes his *Harvard Photometry*, which is the first catalog of photometric magnitudes, including over 4,000 stars. He is able to compile this data because of his newly-invented meridian photometer.

1884 Elie Metchnikoff (1845–1916), Russian-French physiologist and bacteriologist, discovers the antibacterial activity of some white cells, which he labels phagocytes, and propounds the theory of immunity or phagocytosis.

1884 Etienne-Stéphane Tarnier (1828–1897), French obstetrician, invents an incubator for the care of prematurely born infants. It is warmed by kerosene and is used at Paris.

1884 Eugen Baumann (1846–1896), German chemist, discovers the hypnotic drug sulfanol.

1884 Hans Christian Joachim Gram (1853–1938), Danish bacteriologist, invents the Gram staining method; he stains bacteria using one of Ehrlich's methods, and then treats them with iodine solution followed by an alcohol wash, which removes the stain from some but not others. This becomes an important method of classifying bacteria such as penicillin, which is Gram-positive, and streptomycin, which is Gram-negative (no stain).

1884 Hugo von Seeliger (1849–1924), German astronomer, begins a 25-year statistical analysis of the distribution of stars. His estimate of the size of the Milky Way is later modified.

1884 An international conference is held in Washington, D.C., at which Greenwich, England, is chosen as the common prime meridian for the entire world.

1884 Jacobus Henricus Van't Hoff (1852–1911), Dutch physical chemist, publishes his *Études de Dynamique Chemique*, which lays the foundations for chemical kinetics and chemical thermodynamics.

1884 Jean-Albert Pitres, French physician, gives the first classic account of agraphia (also known as dysgraphia), which is the pathologic loss of the ability to write.

1884 Johann Hermann Lie Vogt (1858–1932), Norwegian geologist, publishes an article in which he pioneers the application of physical chemistry to silicate magmas.

1884 Karl Sigmund Franz Crede (1819–1892), German gynecologist, first introduces the procedure of putting a dilute solution of silver nitrate into the eyes of the newborn as a preventive measure against gonorrheal ophthalmia.

1884 Karl Wilhelm von Naegeli (1817–1891), Swiss botanist, publishes his *Mechanisch-Physiologische Theorie der Abstammungslehre*, in which he introduces the notion of "idioplasm" being that part of the protoplasm responsible for its genetic makeup.

1884 Marcel-Alexandre Bertrand (1847–1907), French geologist, suggests that some mountains, like the Alps, were formed by overturned folds and overthrusts.

1884 Otto Wallach (1847–1931), German organic chemist, begins a life-long project to separate one terpene from another (terpenes are isomeric hydrocarbons found in essential oils) and to establish the structure of each. After 25 years of this work, his research forms the basis for the modern perfume industry.

1884 Sigmund Freud (1856–1939), Austrian psychiatrist, first suggests the use of cocaine as a surface anesthetic.

1884 Svante August Arrhenius (1859–1927), Swedish chemist, first proposes the concept of ions being atoms bearing electric charges. He offers this theory as part of his dissertation, in which he argues that molecules of some compounds break up into charged particles when put in a liquid. His ideas are eventually proved correct, and he becomes one of the founders of modern physical chemistry.

1884 Karl Rabl suggests the concept of the individuality of the chromosomes. He argues that each chromosome originates from a preexisting chromosome in the mother cell that is like it in form and size.

1884 Louis Pasteur and coworkers publish a paper entitled *A New Communication on Rabies.* Pasteur proves that the causal agent of rabies can be attenuated, and the weakened virus can be used as a vaccine to prevent the disease. This work serves as the basis of future work on virus attenuation, vaccine development, and the concept that variation is an inherent characteristic of viruses.

1884 Robert Koch (1843–1910), German bacteriologist, discovers the cholera bacillus.

1884 Karl Koller (1857–1944) first uses cocaine as a local anesthetic. He uses it on a patient's eye.

1885 Johann Jakob Balmer (1825–1898), Swiss mathematician and physicist, discovers a simple numerical formula with which the prominent series of lines in the visible region of the hydrogen spectrum can be correlated to wavelength. This is known as the Balmer series.

1885 A supernova is observed in M.31, the Andromeda Galaxy. It is the only recorded extragalactic supernova ever to be barely visible with the naked eye.

1885 Edouard van Beneden (1846–1910), Belgian cytologist, proves that chromosomes persist between cell divisions. He is the first to count the chromosomes and discovers that each species has a fixed number of chromosomes. He also discovers that in the formation of sex cells, the division of chromosomes during one of the cell divisions was not preceded by a doubling; each egg and sperm cell has only half the usual count of chromosomes.

1885 Edward Livingston Trudeau (1847–1915), American physician, founds the Adirondack Cottage Sanatorium at Saranac Lake, New York. As a place to treat incipient consumption in working men and women, it is the first of its kind in the United States.

1885 James Leonard Corning (1855–1923), American surgeon, is the first to use cocaine as a spinal anesthetic.

1885 John William Strutt Rayleigh (1842–1919), English physicist, first proposes his idea of what come to be called "Rayleigh waves." These are a type of surface wave caused by an earthquake and travel on the free surface of an elastic solid. Their motion is both longitudinal and vertical, and of all the seismic waves, they have the strongest effect on a seismograph.

1885 Karl Auer von Welsbach (1858–1929), Austrian chemist, discovers that what had been thought of as one element named didymium is in fact made up of two rare earth elements. He names them praseodymium and neodymium.

1885 Karl Auer von Welsbach (1858–1929), Austrian chemist, invents the incandescent gas mantle. His use of chemicals in the mantle produces a brilliant white glow but is outdone by Edison's electric light.

1885 Louis Pasteur (1822–1895), French chemist, inoculates a boy, Joseph Meister, against rabies. He had been bitten by a rabid dog, and the treatment saves his life. This is the first case of Pasteur's use of an attenuated germ on a human being.

1885 Pierre Marie (1853–1940), French neurologist, first names the disease of giantism "acromegaly."

1885 The Tokyo Observatory is founded.

1885 Victor Babe (1854–1926) of Austria collaborates with André-Victor Cornil (1837–1908) of France to publish *Les Bactéries*, the first complete treatise on bacteriology.

1885 Theodor Escherich (1857–1911) identifies a bacterium inhabiting the human intestinal tract that he names *Bacterium coli* and shows that the bacterium causes infant diarrhea and gastroenteritis. The bacterium is subsequently named *Escherichia coli* or *E. coli*.

1886 Arnold Cahn and P.P. Hepp first introduce acetanilide (antifebrine).

1886 Eugen Goldstein (1850–1930), German physicist, discovers what he calls "Kanalstrahlen," later called channel rays or canal rays. He finds that they travel in the opposite direction to those taken by cathode rays. This marks the beginning of an awareness of protons.

1886 Roland von Eotvos (1848–1919), Hungarian physicist, first introduces the concept of molecular surface tension. His study of Earth's gravitational field, which leads him to invent a precise torsion balance, results in his proof that inertial mass and gravitational mass are equivalent. This proves to be a major principle in Einstein's general theory of relativity.

1886 Clemens Winkler (1838–1904), German chemist, discovers germanium. This new element confirms the validity of Dmitri Mendeleyev's periodic table.

1886 Ernst von Bergmann (1836–1907), German surgeon, first introduces steam sterilization for surgery and establishes the modern standardized aseptic ritual.

1886 Ferdinand-Frédéric-Henri Moissan (1852–1907), French chemist, devises a special electric furnace with which he discovers flourine.

1886 Franz von Soxhlet first suggests that milk given to infants be sterilized.

1886 Joseph von Mehring (1849–1908), German physician, and Oskar Minkowski (1858–1931), Lithuanian physiologist, produce experimental diabetes by the successful surgical removal of the pancreas of a dog.

1886 Marcell Nencki (1847–1901) of Poland first introduces salol (phenyl salicylate), which is used as an antiseptic.

1886 Paul-Louis-Toussaint Héroult (1863–1914), French metallurgist, and Charles Martin Hall (1863–1914), American chemist, independently invent an electrochemical process for extracting aluminum from its ore. This process forms the basis of the huge aluminum industry. Hall makes his discovery in February of this year, and Heroult achieves his in April. Oddly, they both are born in 1863 and die in 1914.

1886 Pierre Marie (1853–1940), French physician, first gives the classic description of acromegaly. This condition of an overactive pituitary gland results in the progressive enlargement of the patient's face, hands, and feet.

1886 Reginald Haber Fitz (1843–1913), American surgeon, first describes the pathology and clinical features of appendicitis. He details how a physician can diagnose the condition and prescribes when an operation is required. It is Fitz who names the disease.

1886 Richard von Krafft-Ebing (1840–1902), German neurologist, publishes his landmark case history study of sexual abnormalities, *Psychopathia Sexualis*, and helps found the scientific consideration of human sexuality.

1886 Theodor Escherich (1857–1911), German pediatrician, publishes his treatise on the intestinal bacteria of infants, which contains the first account of Bacillus coli infections. His work introduces bacteriology to pediatrics.

1886 Viktor Moritz Goldschmidt (1888–1947), Swiss-Norwegian geochemist, publishes the first of his three-volume work, *Index der Kristallformen der Mineralien*, which catalogs the crystal forms of all known minerals.

1886 William Crookes (1832–1919), English physicist, states his theory of cathode ray

tubes, which had been discovered in 1858 by German mathematical physicist Julius Plucker (1801–1868).

1886 Adolf Mayer publishes the landmark article "Concerning the Mosaic Disease of Tobacco." This paper is considered the beginning of modern experimental work on plant viruses. Mayer assumes that the causal agent is a bacterium, although he is unable to isolate it.

1887 Albert Abraham Michelson (1852–1931), German-American physicist, collaborates with the American chemist Edward Williams Morley (1838–1923) to test the age-old hypothesis that Earth moves through luminiferous ether (the supposed light-carrying element that exists outside or above Earth's atmosphere). They use Michelson's interferometer—which splits a beam of light in two, sends each on a different path, and then reunites them—to test out this idea. The failure of this extremely sensitive instrument to detect even the slightest change in the velocity of light proves that the ether does not exist (for it would have had to change slightly if it had gone through a substance). This result overturns all ether-based theories and makes physicists search for some explanation of the invariance of the speed of light.

1887 Ernst Mach (1838–1916), Austrian physicist, is the first to note the sudden change in the nature of the airflow over a moving object that occurs as it approaches the speed of sound. Because of this, the speed of sound in air (under certain temperature conditions) is called Mach 1. Mach 2 is twice that speed and so on.

1887 Anton Weichselbaum (1845–1920), Austrian pathologist, first demonstrates that meningococcus in the spinal fluid is the cause of epidemic cerebrospinal meningitis.

1887 Augustus Desiré Waller (1856–1922), French physiologist, first records the electrical activity of the human heart and lays the foundation for future electrocardiography.

1887 Emil Hermann Fischer (1852–1919), German chemist, studies the structure of sugars and shows the exact nature of the many varieties.

1887 First antitubercular dispensaries are opened in Edinburgh, Scotland.

1887 Herman Frasch (1851–1914), German-American chemist, patents a method for removing sulfur compounds from oil. Once the foul sulfur smell is removed through the use of metallic compounds, petroleum becomes a marketable product.

1887 Hermann Carl Vogel (1842–1907), German astronomer, begins a program of spectroscopic measurement of the radial motions or speed of the stars and introduces the use of photography in stellar spectroscopy

1887 Hermann Michael Biggs (1859–1923), American physician, writes the first published educational material on tuberculosis for the layman.

1887 Oskar Medin (1847–1927), Swedish pediatrician, is the first to recognize the epidemic nature of poliomyelitis.

1887 Oskar Minkowski (1858–1931), Russian-German pathologist and physiologist, first notes the relation between pituitary enlargement and acromegaly.

1887 Victor Hensen (1835–1934), German physiologist and pathologist, creates the term "plankton" to describe the microscopic flora and fauna that live on the ocean floor.

1887 Viktor Meyer (1848–1897), German organic chemist, introduces the term "stereochemistry" for the study of molecular shapes.

1887 Wilhelm Ostwald (1853–1932), Russian-German physical chemist, founds the first learned journal devoted exclusively to physical chemistry. *Zeitschrift für Physikalische Chemie* becomes an influential journal, and it is by Ostwald's efforts that physical chemistry becomes an organized, independent branch of chemistry.

1887 William de Wiveleslie Abney (1843–1920), English astronomer, invents a red-sensitive emulsion that makes it possible for the first time to photograph the solar spectrum in

the infrared. This then makes possible the study of how sunlight is altered as it passes through the atmosphere (since some of the infrared is absorbed by the air).

1887 Theodor Boveri observes the reduction division during meiosis in *Ascaris* and confirms August Weismann's predictions of chromosome reduction during the formation of the sex cells.

1887 Richard Julius Petri (1852–1921) develops a culture dish that has a lid to exclude airborne contaminants. The innovation is subsequently termed the Petri dish.

1887 International Conference for Astrophotography is held in Paris. It decides on a cooperative venture to compile a large-scale map of the heavens together with a catalog of all stars up to the eleventh magnitude. This project will involve 22 observatories in several countries and will take over 50 years to complete.

1888 Heinrich Rudolf Hertz (1857–1894), German physicist, for the first time generates electromagnetic (radio) waves and devises a detector that can measure their wavelength. From this he is able to prove experimentally James Clerk Maxwell's (1831–1879) hypothesis that light is an electromagnetic phenomenon. The work of Hertz not only discovers radio waves but brings together the three main fields of physics: electricity, magnetism, and light.

1888 American Association of Anatomists is founded.

1888 Artificial drinking straws are first introduced. Public awareness of hygiene increases.

1888 Emanuel Libman (1872–1946), American physician, presents the first proven case of an aneurysm being caused by impact.

1888 Emil Maupas (1842–1916), French biologist, traces the actual series of generations of protozoa and finds that after many divisions in *Paramecium*, the stock becomes weakened and the individuals die.

1888 First incubator for infants in the United States is built by William C. Deming.

1888 Lick Observatory on Mt. Hamilton in San Jose, California, is founded. Named after its donor, the American philanthropist James Lick (1796–1876), the observatory has a 26-inch (66-cm) refractor telescope and becomes the first of the great California observatories as well as the first mountaintop observatory. It is turned over to the University of California.

1888 First seismograph in the United States is installed at the Lick Observatory on Mt. Hamilton, near San Jose, California.

1888 Heinrich Wilhelm Gottfried Waldeyer-Hartz (1836–1921), German anatomist, first introduces the word "chromosomes."

1888 James Edward Keeler (1857–1900), American astronomer, studies the rings of Saturn and observes a second major gap in its ring system. This becomes known as the "Keeler gap" as opposed to the first "Cassini gap."

1888 Karl Siegmund Franz Crede (1819–1892), German gynecologist, invents an incubator for premature infants.

1888 Paul-Oscar Blocq (1860–1896), French physician, first describes a condition in which a physically-sound subject is unable to walk or stand because of some mental trauma or conflict suffered. It is known variously as Blocq's disease, abasia, astasia, and hysterical ataxia.

1888 Theodor Heinrich Boveri (1862–1915), German zoologist, discovers and names the "centrosome," the mitotic spindle that appears during cell division. He is also the first to note that chromosomes split as part of the mechanism of reproduction.

1888 Woods Hole Marine Biological Station founded in Woods Hole, Massachusetts. It eventually becomes headquarters for the Woods Hole Oceanographic Institution (1930) and the Marine Biological Laboratory.

1888 Martinus Beijerinck (1851–1931) uses a growth medium enriched with certain nutrients to isolate the bacterium *Rhizobium*, demonstrating that nutritionally-tailored growth media are useful in bacterial isolation.

1888 The Institute Pasteur is founded in France. It opens the following year.

1889 Johann Philipp Ludwig Julius Elster (1854–1920) and Hans Friedrich Geitel (1855–1923), both German physicists, study the photoelectric effect (when an electric current is created upon the exposure of certain metals to light) and produce the first practical photoelectric cells that can measure the intensity of light.

1889 American Psychological Association is founded.

1889 Clarence Dutton (1841–1912), American geologist, proposes the name isostasy for the equilibrium between the lighter (surface) and denser (underground) parts of Earth. When this balance is disturbed by erosion or other forces, a compensating movement can occur.

1889 Edward Emerson Barnard (1857–1923), American astronomer, takes the first photograph of the Milky Way. Taken with large-aperture lenses, his photos reveal much new detail.

1889 Francis Galton (1822–1911), English anthropologist, culminates his work on inheritance and variation with his book *Natural Inheritance.* It influences Karl Pearson (1857–1936) and begins the science of biometrics or the statistical analysis of biological observations and phenomena.

1889 George Ellery Hale (1868–1938), American astronomer, invents the spectroheliograph, which makes it possible to photograph the light of a single spectral line of the sun. Using this, he sees the distribution of calcium in the solar atmosphere.

1889 Hans Buchner (1850–1902), German bacteriologist, first establishes the bactericidal effect of blood serum. He calls this discovery of albuminoids, or protective substances in the blood, "alexins." This is the beginning of immunology theory.

1889 Joaquin Albarran y Dominguez (1860–1912), Cuban-French urologist, is credited with inventing cystoscopes that allow him to systematically catheterize the human ureter. James Brown is also credited with being the first to catheterize the male ureter in 1895.

1889 Pasteur Institute first opens in Paris.

1889 Richard Altmann (1852–1900), German histologist, isolates and names nucleic acid.

1889 The Johns Hopkins Hospital in Baltimore, Maryland, first opens.

1890 Hendrik Anton Lorentz (1853–1928), Dutch physicist, suggests that the atom consists of charged particles whose oscillations can be affected by a magnetic field. This is later confirmed by his pupil, the Dutch physicist Pieter Zeeman (1865–1943), in 1896.

1890 James Alfred Ewing (1855–1935), English physicist, discovers and names the phenomenon of hysteresis, the property of magnetic materials to resist becoming magnetized or demagnetized.

1890 Johannes Robert Rydberg (1854–1919), Swedish physicist, offers an equation containing what comes to be called the Rydberg constant, which interprets the periodicity of the elements in terms of the structure of the atom.

c.1890 Oliver Joseph Lodge (1851–1940), English physicist, invents the coherer, a detector of radio waves that, although replaced, makes him one of the pioneers of early radio communication. He also suggests correctly that the sun emits radio waves.

1890 British Astronomical Association is founded.

1890 Conway Lloyd Morgan (1852–1936), English biologist and psychologist, publishes his major work on animal psychology titled *Animal Life and Intelligence*, in which he is one of the first to use an experimental approach as a complement to observation.

1890 Emil Adolf von Behring (1854–1917), German bacteriologist, discovers the concept of antitoxins. He is able to produce an immunity against tetanus in an animal by injecting it with graded doses of blood serum from an animal suffering from tetanus.

1890 Emil Adolf von Behring (1854–1917), German bacteriologist, uses his new discovery of antitoxins to develop an antitoxin for diphtheria—a disease that usually brought death to the children it attacked.

1890 Franz Hofmeister (1850–1922) of Germany obtains the first crystallization of a protein, albumin.

1890 Hermann Carl Vogel (1842–1907), German astronomer, discovers spectroscopic binaries. These are two stars that are so close together that no telescope (then or now) can see them as separate. Their separate identity is seen clearly however by a spectroscope.

1890 Jacques Loeb (1859–1924), German-American physiologist, offers his theory of tropisms, which describes an organism's involuntary movement as the result of a stimulus.

1890 Karl Pearson (1857–1936), English statistician, is influenced by Francis Galton's work and begins his collaboration with English zoologist Walter Frank Raphael Weldon (1860–1906), which leads to the establishment of the science of biometrics.

1890 Russian Astronomical Society is founded.

1890 Stephen Moulton Babcock (1843–1931), American agricultural chemist, perfects a test for determining the buttermilk content of milk and offers a standard method of grading milk.

1890 The rotary furnace for cement is invented.

1890 William Stewart Halsted (1852–1922), American surgeon, first introduces the use of sterile rubber gloves into the operating room.

1891 George Johnstone Stoney (1826–1911), Irish physicist, studies electrolysis and says that it can best be understood by thinking in terms of "units of electricity." He then proposes the name "electron" for this unit of electricity.

1891 James Dewar (1842–1923), Scottish chemist and physicist, succeeds in building a device that can produce liquid air and liquid oxygen in large quantities. He then is able to detail their strange qualities.

1891 Albert Abraham Michelson (1852–1931), German-American physicist, measures the diameters of the known satellites of Jupiter using a stellar interferometer of his own design

1891 Alfred Werner (1866–1919), German-Swiss chemist, develops his coordination theory, which suggests that atoms or groups of atoms could be distributed around a central atom in accordance with fixed geometric principles regardless of valence.

1891 Charles Edouard Brown-Sequard (1817–1894), English physician, develops the idea of internal secretions (hormones).

1891 Charles Frederick Cross (1855–1935), English chemist, invents viscose rayon. He improves early rayon by dissolving cellulose in carbon disulfide and squirting the viscous solution out of fine holes. The fine threads of viscose rayon are formed as the solvent evaporates. By 1908, this viscous solution is forced through a narrow slit, forming thin, transparent sheets of what comes to be known as "cellophane."

1891 Edward Charles Pickering (1846–1919) and his brother, William Henry Pickering (1858–1938), both American astronomers, establish an astronomical observatory in Peru.

1891 Edward Goodrich Acheson (1856–1931), American inventor, discovers that carbon heated with clay yields an extremely hard substance. He names it carborundum and eventually finds it to be a compound of silicon and carbon. For half a century it remains second only to a diamond in hardness and becomes very useful as an abrasive.

1891 First child is treated with the diphtheria antitoxin.

1891 Friedrich Daniel von Recklingshausen (1833–1910), German pathologist, describes osteitis fibrosa cystica in detail. It results from an over-active parathyroid gland. It is also called Engel-Recklingshausen disease.

1891 Hermann Henking (1858–1942), German zoologist, describes sex chromosomes and autosomes.

1891 Marcel Eugène E. Gley (1857–1930), French physiologist, demonstrates that the parathyroid glands are essential for life.

1891 Nils Christofer Dunér (1839–1914), Swedish astronomer, discovers that the sun does not rotate uniformly. Its equatorial region has a rotational period of about

25 days, but its poles are about 38 days. This phenomenon still has not been satisfactorily explained.

1891 Paul Ehrlich (1854–1915), German bacteriologist, discovers that methyl blue dye immobilizes malaria bacterium and begins searching for other, more potent microbial dyes.

1891 Paul Eugen Bleuler (1857–1939), Swiss psychiatrist, publishes his *Die Gruppe der Schizophrenein*, in which he reorganizes the various syndromes known as dementia praecox and designates a new disease he calls "schizophrenia."

1891 Maximilian Franz Joseph Wolf (1863–1932), German astronomer, adapts photography to the study of asteroids and demonstrates that stars appear as points in photographs while asteroids show up as short streaks. He makes the first discovery of an asteroid from photographs. During his lifetime he discovers over 500 asteroids in this manner.

1892 George Francis Fitzgerald (1851–1901), Irish physicist, attempts to explain the failed Michelson-Morley experiment of 1887 and offers what comes to be called the Fitzgerald contraction. He suggests that when in motion, a body is shorter (along its line of motion) than when it is at rest, and that this shortening may have affected the instruments used in that famous experiment. This idea eventually becomes an integral part of Albert Einstein's special theory of relativity.

1892 August F. Weismann (1834–1914), German biologist, publishes his book *Das Keimplasma: Eine Theorie der Vererbung*, which contributes to the founding of the science of genetics. He offers his germplasm theory, which also leads him to predict correctly the phenomenon of meiosis (the splitting of paired chromosomes).

1892 Edward Emerson Barnard (1857–1923), American astronomer, studies a nova in the constellation Auriga and is the first to note the puff of gaseous matter it gives off. This is clear evidence that a nova is an exploding star.

1892 François-Alphonse Forel (1841–1912), Swiss physician and naturalist, coins the term "limnology" to designate the study of the flora and fauna of lakes (fresh water).

1892 Francis Galton (1822–1911), English anthropologist, begins his pioneering scientific studies of the nature of intelligence.

1892 Friederich Leopold Goltz (1834–1902), German physiologist, describes the loss of all but reflex action in decerebrate (having the cerebrum of the brain removed) dogs.

1892 James Dewar (1842–1923), Scottish chemist and physicist, improves the Violle vacuum insulator by constructing a double-walled flask with a vacuum between the walls. He then coats all sides with silver so heat will be reflected and not absorbed. His Dewar flask keeps hot liquids hot and cold liquids cold. This flask eventually becomes the first Thermos bottle.

1892 Joseph Paxon Iddings (1857–1920), American geologist, is named by the University of Chicago as the first-ever Professor of Petrology.

1892 Jules-Henri Poincaré (1854–1912), French mathematician, publishes the first of his three-volume work *Les Methodes Nouvelles de la Mécanique Céleste*. The powerful, new mathematical techniques he applies to celestial mechanics begin the use of rigorous methods in this discipline.

1892 Pyotr Nicolaievich Lebedev (1866–1912), Russian physicist, argues that if a tiny particle were placed near the sun, it would be influenced not only by that body's gravitational forces but by the repulsive force emitted by its light rays. This idea is preliminary to his 1901 proof that light does exert pressure.

1892 Richard Friedrich Johann Pfeiffer (1858–1945), German bacteriologist, announces his discovery of the influenza bacillus. Also making the same independent discoveries are P. Canon and Japanese bacteriologist Shibasaburo Kitasato (1856–1931).

1892 Standardization of organic chemistry nomenclature is achieved at the Geneva Conference, which agrees that for name endings, all alcohols will be "ol," saturated

hydrocarbons will end in "ane," aldehydes in "al," and ketones in "one."

1892 Theobald Smith (1859–1934), American pathologist, and F.L. Kilbourne first demonstrate the transmission of bovine piroplasmosis (Texas fever) by ticks.

1892 Wilhem Winternitz (1835–1917) of Bohemia founds the first hydropathic establishment or hydrotherapeutic clinic at Kaltenleutgeben. The application and use of water, especially cold baths, for therapeutic purposes was very much in vogue at this time.

1892 George M. Sternberg (1838–1915) publishes his *Practical Results of Bacteriological Researches.* Sternberg's realization that a specific antibody was produced after infection with vaccinia virus and that immune serum could neutralize the virus became the basis of virus serology.

1892 Edward Emerson Barnard (1857–1923), American astronomer, discovers a fifth satellite around Jupiter. Since Galileo's discovery of the first four satellites, no one had ever seen another. It is the last satellite to be discovered without the aid of photography. It eventually is named Amalthea.

1893 Oliver Heaviside (1850–1925), English physicist and electrical engineer, publishes his *Electromagnetic Theory*, in which he posits that an electric charge would increase in mass as its velocity increases. This is an anticipation of Albert Einstein's special theory of relativity.

1893 Wilhelm Wien (1864–1928), German physicist, conducts black-body research and finds that the wavelengths emitted reach a peak at some intermediate level. He then states his displacement law: Maximum wavelength is inversely proportional to the absolute temperature of the body.

1893 Charles Talamon (1850–1929), French physician and bacteriologist, and colleagues Isidore Straus (1845–1912) and Johannas Petruschky perfect the technique of aseptically drawing blood from individuals with infections and biologically culturing it.

1893 Ernst Julius Öpik (1893–1985), Estonian astronomer, works out his meteor ablation theory, telling how meteors burn up during their entry through Earth's atmosphere.

1893 Ferdinand-Frédéric-Henri Moissan (1852–1907), French chemist, creates an electric furnace that becomes key to high temperature and pressure studies.

1893 Ferencz Posepny (1836–1895), Bohemian geologist, publishes his article "Über die Genesis der Erzlagerstatten," in which he writes about the genesis of ore deposits. He becomes an expert in this area, and his work helps to introduce mining geology into the school curricula.

1893 First successful gastrectomy (partial or total removal of the stomach) in the United States is performed by John Montgomery Baldy (1860– 1934), American surgeon. There are records of two earlier such operations in the United States—one by Conner in 1883 and the other by Augustus C. Bernays in 1887. It is not known if either was successful.

1893 Henry Shaler Williams (1847–1918), American geologist, publishes an article in which he is the first to use the term "geochronology" to describe the geologic time scale.

1893 Liberty Hyde Bailey (1858–1954), American botanist, publishes the first detailed study of the growth of plants under artificial light.

1893 Sigmund Freud (1856–1939), Austrian psychiatrist, describes paralysis originating from purely mental conditions and distinguishes it from that of organic origin.

1893 Hans Adolf Eduard Driesch (1867–1941) discovers that he can separate sea urchin embryos into individual cells, and that the separated cells continue to develop. Driesch concludes that all the cells of the early embryo are capable of developing into whole organisms. Therefore, embryonic cells are equipotent, but differentiated and developed in response to their position within the embryo.

1893 William Bateson (1861–1926) publishes *Materials for the Study of Variation,* which emphasizes the importance of discontinuous variations (the kinds of variation studied by Gregor Mendel; 1822–1884).

1894 Joseph John Thomson (1856–1940), English physicist, announces that his experiments show the velocity of cathode rays is significantly lower than that of light.

1894 Albrecht Penck (1858–1945), German geologist, publishes his *Morphologie der Erdoberflache*, which is the first comprehensive textbook of geomorphology.

1894 Carl Ludwig Schleich (1859–1922), German surgeon, introduces infiltration anesthesia.

1894 Edward Livingston Trudeau (1847–1915), American physician, founds the first research laboratory in the United States for the study of tuberculosis.

1894 First embryological journal is founded, *W. Roux Archiv für Entwicklungsmechanik.*

1894 First free hospice for terminal cancer patients is established in the United States by Rose Lathrop.

1894 First major epidemic of poliomyelitis in the United States breaks out.

1894 Henri Deslandres (1853–1948), French astrophysicist, invents the spectroheliograph independently of George Ellery Hale. This instrument proves invaluable to studies of the sun.

1894 Henry Horatio Dixon (1869–1953), Irish botanist, and John Joly (1857–1933), Irish geologist and physicist, offer their tension theory explaining the ascent of sap in trees.

1894 John William Strutt Rayleigh (1842–1919), English physicist, and William Ramsay (1852–1916), Scottish chemist, succeed in isolating a new gas in the atmosphere that is denser than nitrogen and combines with no other element. They name it "argon," which is Greek for inert. It is the first of a series of rare gases with unusual properties whose existence had not been predicted.

1894 Max Rubner (1854–1932), German physiologist, makes accurate caloric measurements of food and discovers that the energy produced by food being consumed by the body is the same amount as if that quantity had been consumed in a fire. He thus applies the laws of thermodynamics to the living world as well as the inanimate.

1894 The Paris Observatory begins the compilation of a huge photographic atlas of the moon. It takes nearly 20 years to produce but remains unsurpassed for nearly 50 years.

1894 Percival Lowell (1855–1916), American astronomer, opens his own major observatory in Flagstaff, Arizona, and begins his fifteen-year study of Mars. He becomes the foremost proponent of the intelligent-life-on-Mars school of thought. The Lowell Observatory remains today one of the world's major astronomical centers.

1894 Shibasaburo Kitasato (1856–1931), Japanese bacteriologist, and Swiss bacteriologist Alexandre Emile John Yersin (1863–1943) independently discover the plague bacillus. Yersin develops a serum against the disease.

1894 Wilhelm Ostwald (1853–1932), Russian-German physical chemist, determines that a catalyst can only speed up a reaction and not actually create one.

1894 Guglielmo Marconi (1874–1937), Italian electrical engineer, uses Hertz's method of producing radio waves and builds a receiver to detect them. He succeeds in sending his first radio waves 30 feet to ring a bell. The next year, his improved system can send a signal one mile and a half.

1895 First standardization of anatomical nomenclature is achieved by Swiss-German anatomist Wilhelm His (1831–1904). He also founds histogenesis, the study of the development of the human embryo, with his work in the 1880's.

1895 Jean Baptiste Perrin (1870–1942), French physicist, demonstrates conclusively that cathode rays must consist of negatively charged material and are therefore particles rather than waves.

1895 Pierre Curie (1859–1906), French chemist, studies the effect of heat on magnetism and shows that there is a critical temperature point above which magnetic properties will disappear. This comes to be called the Curie point.

1895 Wallace Clement Sabine (1868–1919), American physicist, is asked by Harvard University to ascertain why lecturers in a new building cannot be heard. With his studies of the problem, he founds the science of architectural acoustics.

1895 The *Astrophysical Journal* is founded in Chicago, Illinois. It becomes an authoritative, modern periodical in its field.

1895 Bernard Sachs (1858–1944), American physician, publishes *A Treatise on the Nervous Diseases of Children*, which is the first book in the United States on this subject.

1895 Heinrich Irenaeus Quincke (1842–1922), German physician, conducts the first lumbar puncture or spinal tap to study cerebrospinal fluid and for diagnosis and treatment.

1895 John William Harshberger (1869–1929), American botanist, first introduces the word "ethnobotany."

1895 Louis Carl Heinrich Paschen (1865–1947), German physicist, studies the optical spectrum of the newly-discovered helium and establishes its spectral lines, showing it is identical to the solar helium discovered by Pierre-Jules-César Janssen and Joseph Lockeyer.

1895 Nathaniel Southgate Shaler (1841–1906), American geologist, publishes an article in which he describes the effect of the withdrawal of sea water from oceans to form ice caps and the consequent drop in sea level.

1895 Paul Walden (1863–1957), Russian-German chemist, discovers he can alter the effect a substance produces without changing the substance, producing what comes to be known as the "Walden inversion." Studies of this phenomenon have since led to greater understanding of all stages of reaction mechanisms.

1895 Richard Friedrich Johann Pfeiffer (1858–1945), German physician and bacteriologist, introduces bacteriolysis or the concept of antibodies when he discovers that the abdominal fluids of immunized guinea pigs would dissolve cholera bacilli that had been introduced into the abdomen.

1895 Robert Grant Aitken (1864–1951), American astronomer, joins the staff of Lick Observatory at Mt. Hamilton, California, and begins 40 years of astronomical observations. During this time, he discovers approximately 3,000 binary star systems.

1895 Solon Irving Bailey (1854–1931), American astronomer, makes a photographic discovery of variable star clusters, now known as RR Lyrae stars.

1895 William Ramsay (1852–1916), Scottish chemist, discovers helium in a mineral named cleveite. It had been speculated earlier that helium existed only in the sun, but Ramsay proves it also exists on Earth. It is discovered independently the same year by Swedish chemist and geologist Per Theodore Cleve (1840–1905). Helium is an odorless, colorless, tasteless gas that is also insoluble and incombustible.

1895 James Edward Keeler (1857–1900), American astronomer, observes the spectrum of Saturn and its rings and shows that the rings do not rotate as a unit but that the inner rings have a shorter period. This is the first observational proof that the rings are not solid but consist of particles.

1895 Guglielmo Marconi (1874–1937), Italian electrical engineer, becomes convinced that radio has enormous potential when he is able to transmit and receive sound over a hill that blocks his line of sight.

1895 Wilhelm Konrad Röntgen (1845–1923), German physicist, discovers x rays, initiating the modern age of physics and revolutionizing medicine. While working on cathode ray tubes and experimenting with luminescence, he notices that a nearby sheet of paper that is coated with a luminescent substance glows whenever the tube is turned on. For seven weeks he continues to experiment, and near the end of the year is able to report the basic properties of the unknown rays he names "X-rays."

1895 Wilhem Konrad Röntgen (1845–1923), German physicist, first communicates his discovery of x rays in his paper "Über eine neue Art von Strahlen." He tells how this unknown ray or radiation can affect photographic plates, and that wood, paper, and aluminum are transparent to it. It also can ionize gases and does not respond to electric or magnetic fields nor exhibit any properties of light. This discovery leads to such a stream of ground-breaking discoveries in physics that it has been called the beginning of the second Scientific Revolution.

1895 John Cox is the first U.S. physician to use x rays an as adjunct to surgery.

1896 Charles Edouard Guillaume (1861–1938), Swiss-French physicist, discovers invar (an iron-nickel alloy), which proves to be the unchanging metal for which he is searching. Its low cost and relative lack of change with temperature make it an ideal material for precision instruments.

1896 Charles Thomson Rees Wilson (1869–1959), Scottish physicist, invents the Wilson cloud chamber. This new instrument proves to be a powerful tool for physicists, as it makes visible and allows the photographing of the paths or trajectories of charged particles.

1896 Guglielmo Marconi (1874–1937), Italian electrical engineer, travels to England and applies for and obtains the first patent in the history of radio. By this time, he has sent and received a radio signal over nine miles.

1896 Bartolomeo Gosio of Italy first identifies and isolates mycophenolic acid—an antibiotic and a toxic product that comes to be studied in the 1970s for its anti-tumor properties.

1896 Carl Schroter (1855–1939), German botanist, introduces the term "autoecology," referring to the study of the relations between a single species and its environment.

1896 Christiaan Eijkmann (1858–1930), Dutch physician, first produces a deficiency disease experimentally (beriberi in birds). This becomes an important step in the discovery of trace substances called vitamins.

1896 Edmund Beecher Wilson (1856–1939), American zoologist, publishes his major work, *The Cell in Development and Heredity*, in which he connects chromosomes and sex determination. He also correctly states that chromosomes affect and determine other inherited characteristics as well.

1896 Emil Knauer (1867–1935), Hungarian gynecologist, and Josef Halban (1870–1937), Austrian gynecologist, independently prove the existence of ovarian hormones by implanting ovarian tissue into castrated rabbits.

1896 Emil Pierre Marie Van Ermengem (1851–1932), Belgian physician and bacteriologist, discovers the anaerobic bacillus causing botulism.

1896 First radiograph (x ray) of an oil painting is made by Walter Koenig of Germany. X rays soon prove capable of determining whether one painting has been painted over another.

1896 Henry Augustus Rowland (1848–1901), American physicist, prepares a map of the solar spectrum that gives the precise wavelength of some 14,000 lines. He is able to obtain this high level of precision because of a new method he devises for scratching fine, evenly-spaced gratings on concave metal or glass.

1896 Hermann Strauss, German physician, first uses x rays to investigate a patient's gastrointestinal tract.

1896 Johannes Eugenius Bülow Warming (1841–1924), Danish botanist, publishes his *Plantesamfund*, which is generally regarded as beginning the study of plant ecology. It is published in English in 1902 as *Oecology of Plants: An Introduction to the Study of Plant Communities.*

1896 John Martin Schaeberle (1853–1924), German astronomer, detects the very dim companion star of the star Procyon. This is the first indication that such dim or dwarf stars are not as rare as believed. In time, enough are found to form their own class.

1896 Joseph-François-Felix Babinski (1857–1932), French physician, discovers the large toe reflex that comes to bear his name. The lack of this involuntary backward-bending of the big toe after the sole of the foot has been stimulated indicates a neurological disorder.

1896 Ludwig Rehn (1849–1930), German surgeon, is credited with being the first to suture a wound in a human heart successfully. There is also a claim that a surgeon named Dalton repaired a stab wound of the heart in 1891.

1896 Max von Gruber (1835–1927), German bacteriologist, and Herbert Edward Durham (1866–1945), English bacteriolo-

gist, discover agglutination. This phenomenon of blood clumping together occurs when the antibodies it contains react to something introduced, like bacteria.

1896 Scipione Riva-Rocci (1863–1903) of Italy invents the mercury sphygmomanometer, which is the precursor of the modern blood-pressure instrument.

1896 William Joseph Dibdin (1850–1925), English engineer, and his colleague Schweder improve the sewage disposal systems in England with the introduction of a bacterial system of water purification. These improvements greatly reduce the number of water-borne diseases like typhoid fever.

1896 First radiograph (x ray) in England is made by A.A. Campbell-Swinton (1863–1930), English engineer.

1896 First radiograph (x ray) image to be published in the United States appears in the *New York Medical Record.*

1896 The *British Journal of Photography* reports on the first museum artifact to be x-rayed (Egyptian mummies).

1896 Antoine Henri Becquerel (1852–1908), French physicist, studies fluorescent materials to see if they emit the newly-discovered x rays and discovers instead that uranium produces a natural ray that is eventually called "radioactivity" in 1898 by the Polish-French chemist Marie Sklodowska Curie (1867–1934). This is the first observation of natural radioactivity.

1896 Dental radiography (x rays) begins as William James Morton (1845–1920), American neurologist and x-ray pioneer, reads a paper to the New York Odontological Society. He tells how teeth are more dense than bone and give excellent images—even teeth that have not emerged from the gum.

1896 First radiological journal, *Archives of Clinical Skiagraphy*, appears in London. It soon changes its name to the *Archives of the Roentgen Society.*

1896 First to use x rays for a scientifically therapeutic purpose is Leopold Freund (1868–1944), Bohemian physician, who regularly x-rays a five-year-old girl to treat her hirsuitism (excessive body and facial hair). After twelve days, her hair begins to fall out. This case marks the first use of radiotherapy.

1896 Pieter Zeeman (1865–1943), Dutch physicist, discovers the magneto-optical effect that bears his name. He shows that the spectral lines of certain elements are split into three components when the sample is in a strong magnetic field perpendicular to the light path. When the field is parallel to the light path, the lines split into two. This is later used to study the fine structure of the atom.

1897 Alexander Stepanovich Popov (1859–1906), Russian physicist, experiments with the newly-discovered radio waves and is the first to send a signal from ship to shore over a distance of three miles. Although he does not exploit the full potential of radio waves, he does work on methods of receiving them over long distances a year before Guglielmo Marconi does.

1897 Charles Proteus Steinmetz (1865–1923), German-American electrical engineer, completes a major theoretical work in which he works out in complete mathematical detail the intricacies of alternating current (a.c.). This work makes possible the eventual victory of alternating over direct current (d.c.) and is the foundation of the modern electrical industry.

1897 Joseph John Thomson (1856–1940), English physicist, discovers the electron. He conducts cathode ray experiments and concludes that the rays consist of negatively charged "electrons" that are smaller in mass than atoms. He goes on to propose the first theory of atomic structure, stating that these sub-atomic electrons are the constituents of all matter. Although an inadequate theory, it is a good beginning.

1897 Karl Ferdinand Braun (1850–1918), German physicist, modifies a cathode ray tube so that the streaming electrons are affected by the electromagnetic field of a varying current. This results in his invention of the oscillograph or oscilloscope, whose ability to finely vary an electric current makes it the first step toward television and radar.

c. 1897 Richard Wilhelm H. Abegg (1869–1910), German chemist, begins to pursue the new electronic view of the atom and determines that its outermost electron shell determines its properties.

1897 Alvan Graham Clark (1832–1897), American astronomer, completes the construction of the massive 40-inch (1-m) Yerkes telescope. Clark's reputation is for building some of the best telescopes in the world, and this one proves to be the largest refracting telescope in existence. It remains so today, since any larger ones have been reflecting telescopes. The mirrors in large reflectors are easier to build and maintain than the large lenses used in refractors.

1897 Yerkes Observatory at Williams Bay, Wisconsin, is completed. Organized and planned by American astronomer George Ellery Hale (1868–1938), it is paid for by American streetcar magnate Charles Tyson Yerkes (1837–1905). The 40-inch (1-m) refracting telescope is the largest of that type ever built.

1897 Eduard Buchner (1860–1917), German chemist, publishes *Alkoholische Görung ohne Hefezellen*, in which he proves that a cell-free extract of yeast can catalyze glucose (convert sugar to carbon dioxide and alcohol). This establishes that living cells are not essential for fermentation and marks the beginning of enzyme chemistry.

1897 Emil Herman Fischer (1852–1919), German chemist, first synthesizes caffeine, theobromine, xanthine, guanine, and adenine.

1897 Georges Claude (1870–1960), French technologist, reduces the dangers of acetylene explosion by dissolving it in acetone.

1897 Hamilton Young Castner (1859–1899), American chemist, invents the electrolytic method of isolating sodium and chlorine from brine, and forms, with his colleague Kellner, the Castner-Kellner electrochemical process for making caustic soda.

1897 Havelock Ellis (1859–1939), English physician, publishes the first of his seven-volume work *Studies in the Psychology of Sex*. This contributes to the more open discussion of human sexuality and supports sex education.

1897 Industrial radiography begins as Wilhelm Konrad Röntgen (1845–1923), German physicist, x-rays his hunting rifle, allowing examination of the metal for internal flaws. The industrial use of x rays will become a standard, non-destructive testing procedure.

1897 John Jacob Abel (1857–1938), American physiologist and chemist, isolates epinephrine (adrenalin). This is the first hormone to be isolated.

1897 Kiyoshi Shiga (1871–1951) of Japan discovers the bacillus of dysentery.

1897 New York State adopts a law for the compulsory notification of tuberculosis.

1897 Paul Sabatier (1854–1941), French chemist, discovers via a lead experiment that nickel has properties as a catalyst. He develops nickel catalysis, which eventually makes possible the formation of edible fats like margarine and shortening from inedible plant oils.

1897 Raymond-Jacques-Adrien Sabouraud (1864–1938), French dermatologist, first cultivates the acne bacillus.

1897 First whole-body radiograph (x ray) of a living person taken in a single exposure is made by American neurologist William James Morton (1845–1920).

1898 James Dewar (1842–1923), Scottish chemist and physicist, achieves the large-scale production of liquid hydrogen. A year later he is able to solidify hydrogen. This enables him to conduct his research in cryogens, since he can now reach a temperature only fourteen degrees above absolute zero.

1898 Philipp Eduard Anton von Lenard (1862–1947), Hungarian-German physicist, experiments with a cathode ray tube and discovers that the power of substances to absorb these rays depends on their density and not on their chemical make-up. He also finds that absorption decreases with increasing velocity of the rays.

1898 Carl Benda (1857–1932) of Germany discovers and names the mitochondria previously seen by Richard Altmann (1852–1900).

1898 Charles Reid Barnes (1858–1910), American botanist, proposes the term "photosynthesis."

1898 Davis and Varmier are the first to use x rays for obstetrical diagnoses.

1898 Emil Herman Fischer (1852–1919), German chemist, isolates the purin nucleus of uric acid compounds and elucidates their structure in detail. This turns out to be highly significant, for purines are an important part of a group of substances called nucleic acids that are found, in the next century, to be the key molecules of living tissues.

1898 First state-run sanatorium for tuberculosis in the United States opens in Massachusetts.

1898 First tuberculosis clinic in the United States opens in New York.

1898 George Howard Darwin (1845–1912), English astronomer, publishes *The Tides and Kindred Phenomena in the Solar System*, in which he discusses the effects of tidal friction on the Earth-Moon system and theorizes that the moon was formed from matter pulled away from the still-molten Earth by solar tides. He is the second son of Charles Darwin (1809–1882).

1898 Gustav Killian (1860–1921), German laryngologist, introduces the direct bronchoscopy—a tubular instrument that is illuminated and used for examining the lungs' bronchi or for passing instruments into them.

1898 Hans Goldschmidt (1861–1923), German chemist, develops a method of producing an oxide-aluminum mixture called thermite that becomes ideal for welding.

1898 Henry Koplik (1858–1927), American physician, discovers the early diagnostic signs or spots for measles (called Koplik's spots).

1898 Heinrich Dreser (1860–1924), while working for Farbenfabriken Bayer, first introduces heroin.

1898 John Newport Langley (1852–1925), British physiologist, first coins the term "autonomic nervous system."

1898 Kiyoshi Shiga (1870–1957) of Japan develops an immune serum for bacillary dysentery.

1898 Martinus Wilhelm Beijerinck (1851–1931), Dutch botanist, discovers and names the causative agent of the tobacco mosaic disease. He describes it as a new type of microscopically-visible organism, which eventually comes to be known as a virus.

1898 Ronald Ross (1857–1932), English physician, shows that the bird malaria organism is carried by a mosquito.

1898 Theobald Smith (1859–1934), American pathologist, makes the first clear distinction between human and bovine tubercule bacili.

1898 William Ramsay (1852–1916), Scottish chemist, discovers the new element krypton. He obtains it only after months of boiling down liquid air. He also obtains the inert gases xenon and neon with the same process.

1898 G. Witt, director of the Urania Observatory in Berlin, Germany, discovers the planetoid Eros, which later becomes important in determining solar parallax.

1898 Marie Sklodowska Curie (1867–1934), Polish-French chemist, discovers thorium, which she proves is radioactive.

1898 Marie Sklodowska Curie (1867–1934), Polish-French chemist, and her husband, the French chemist Pierre Curie (1859–1906), refine pitchblende and detect a radioactive substance that they name polonium after her homeland.

1898 Marie Sklodowska Curie (1867–1934), Polish-French chemist, and her husband, the French chemist Pierre Curie (1859–1906), detect only a trace of still another radioactive substance in pitchblende and name it radium. They spend the next four years refining eight tons of pitchblende to obtain one ounce of radium. Their discoveries in radioactivity inaugurate the investigation of this new field.

1899 Emile Hilaire Amagat (1841–1915), French mathematician and physicist, publishes *The Laws of Gases.* During his studies on the behavior of gases under various pressures and temperatures, he finds that the more a gas is compressed, the more it deviates from the Boyle-Mariotte law.

1899 Ernest Rutherford (1871–1937), British physicist, discovers that radioactive substances give off different kinds of rays. He names the positively charged ones alpha rays and the negative ones beta rays.

1899 Joseph John Thomson (1856–1940), English physicist, measures the charge of the newly-discovered electron.

1899 A bibliography of world astronomical literature, *Astronomischer Jahrebericht*, is founded in Germany.

1899 André-Louis Debierne (1874–1949), French chemist, discovers the radioactive element actinium.

1899 Aspirin is first introduced on the market by the German pharmaceutical firm Farbenfabriken Bayer.

1899 First International Dental Congress is held in Paris.

1899 George Henry Falkiner Nuttall (1862–1937), American biologist, first summarizes the role of insects, arachnids, and myriapods as transmitters of bacterial and parasitic diseases.

1899 Jacques Loeb (1859–1924), German-American physiologist, induces parthenogenesis in the sea urchin. He demonstrates what is essentially artificial fertilization when he induces an unfertilized egg to develop to maturity by means of proper environmental changes.

1899 James Dewar (1842–1923), Scottish chemist and physicist, builds a large device with which he first solidifies hydrogen. He is able to obtain a temperature of only fourteen degrees above absolute zero.

1899 Johan Thor Stenbeck first treats skin cancer cases with x rays.

1899 Johann Georg Hagen (1847–1939), who later becomes director of the Specola Vaticana, publishes the *Atlas Stellarum Variabilium*, the first general atlas of variable stars.

1899 Julius Elster (1854–1920) of Germany and Hans Friedrich Geitel (1855–1923), German physicist, demonstrate that the external effects do not influence the intensity of radiation. They are also the first to characterize radiation as being caused by changes that take place within the atom.

1899 Simon Newcomb (1835–1909), Canadian-American astronomer, completes his mammoth work of producing new tables for the motions of the moon and the planets. These are an improvement on all preceding calculations.

1899 Thomas George Bonney (1833–1923), English geologist, discovers diamonds in eclogite rocks in South Africa and first proposes the theory that eclogite is the parent rock of diamonds.

1899 William Henry Pickering (1858–1938), American astronomer, discovers the ninth of Saturn's satellites. Named Phoebe, it is the outermost of Saturn's satellites and also the first satellite to be discovered by the use of photography.

1899 William Jackson Pope (1870–1939), English chemist, discovers the first optically active (able to polarize light) compound that contains no carbon atoms. This proves that the Van't Hoff theory applies to atoms other than carbon.

1899 William Wallace Campbell (1862–1938), American astronomer, uses a spectroscope and discovers that Polaris is actually a system of three stars.

1899 A meeting to organize the Society of American Bacteriologists is held at Yale University. The society will later become the American Society for Microbiology.

1899 First proven cure of a cancer patient by x-ray treatment is made in Sweden by Tage Anton Ultimus Sjögren (1859–1939), Swedish surgeon. The patient's squamous cell carcinoma (skin cancer) of the cheek is cured by x rays and a minor operation.

1900 Max Karl Ernst Ludwig Planck (1858–1947), German physicist, publishes his revolutionary paper on quantum physics. He tells of his discovery that light or energy is not found in nature as a continuous wave or flow but is emitted and absorbed discontinuously in little packets or "quanta." Further, each quantum or packet of energy is indivisible. Planck's entirely new notion of the quantum seemed to contradict the mechanics of Isaac Newton and the electromagnetics of James Clerk Maxwell, and

replace them with new rules. In fact, his quantum physics were new rules in a new game of physics—the game of the very fast and the very small. His theory is soon applied (by Albert Einstein) and incorporated (by Niels Bohr) and becomes the watershed between all physics that comes before it (classical physics) and all that is after (modern physics).

1900 Paul Ulrich Villard (1860–1934), French physicist, discovers what come to be called gamma rays. While studying the recently-discovered radiations from uranium, he finds that in addition to the alpha rays and beta rays, there are other rays, unaffected by magnets, that are like x rays but shorter and more penetrating.

1900 Carl Benda (1857–1932) of Germany demonstrates the connection between acromegaly and eosinophil adenoma of the anterior pituitary.

1900 David Gill (1843–1914), Scottish astronomer, completes a photographic sweep of the southern stars for the first time. His *Cape Photographic Durchmusterung* catalogs over 450,000 stars.

1900 Edward Walter Maunder (1851–1928), English astronomer, publishes a history of the Royal Observatory at Greenwich. During his historical studies, he notices that from 1645 to 1715 there is a marked lack of sunspot reports, and he suggests that there are periods when few if any occur. Later astronomers confirm his theory, calling that period the "Maunder minimum."

c. 1900 Emil Wiechert (1861–1928), German geologist, introduces a more sensitive seismograph based on the principle of an inverted pendulum.

1900 Ernst Wertheim (1864–1920), German surgeon, first introduces the operation for cancer of the cervix called a radical hysterectomy.

1900 Friedrich Ernst Dorn (1848–1916), German physicist, analyzes the gas given off by (radioactive) radium and discovers the inert gas he names radon. This is the first clear demonstration that the process of giving off radiation transmutes one element into another.

c. 1900 Friedrich Johann Karl Becke (1855–1931), Czech mineralogist, invents the method of identifying minerals by their light-refracting properties.

1900 Harry Hamilton Johnston (1858–1927), English explorer, discovers hitherto unknown okapi, a rare African mammal closely related to the giraffe. It is the last large land mammal to be discovered.

1900 Karl Landsteiner (1868–1943), Austrian-American physician, discovers the different types of human blood. He finds there are different blood groups (A, B, AB, and O), which differ in the capacity of their serum to clump together. Once this is known, transfusions can become safe and practical.

1900 Moses Gomberg (1866–1947), Russian-American chemist, discovers triphenylmethyl, the first example of a free carbon radical. Carbon has four valences, but triphenylmethyl uses only three valences of the central carbon atom, leaving one free or unfilled. Free radicals eventually prove very important to chemical reactions.

1900 Paul Karl Ludwig Drude (1863–1906), German physicist, proposes the first model for the structure of metals. His model explains the constant relationship between electrical conductivity and the heat conductivity in all metals.

1900 Robert Gersuny (1844–1924), Bohemian physician, introduces prosthetic paraffin injections.

1900 Sigmund Freud (1856–1939), Austrian psychiatrist, offers his theories on the unconscious mind in his book on the interpretation of dreams, *Die Traumdeutung*. His new method of probing the human mind via psychoanalysis eventually becomes an important part of psychiatry.

1900 Thomas Chrowder Chamberlin (1843–1928), American geologist, and Forest Ray Moulton (1872–1952), American astronomer, collaborate and advance the planetesimal theory of the origin of the universe. They suggest that a star passed close to the sun and that both bodies had matter raised by tidal forces, with these eventually

cooling and coalescing into planets. This theory is no longer held.

1900 Vladimir Nikolaevich Ipatieff (1867–1952), Russian-American chemist, discovers the role catalysts can play in explosions when he finds that organic reactions taking place at high temperatures can be influenced in their course by varying the nature of the substance with which they are in contact.

1900 Walter Reed (1851–1902), American surgeon, discovers that the yellow fever virus is transmitted to man by a mosquito. This is the first demonstration of a viral cause of a human disease.

1900 Karl Pearson develops the chi-square test.

1900 Thomas H. Montgomery studies spermatogenesis in various species of Hemiptera. He concludes that maternal chromosomes only pair with corresponding paternal chromosomes during meiosis.

1900 Paul Erlich (1854–1915) proposes the theory concerning the formation of antibodies by the immune system.

1900 Hugo Marie De Vries (1848–1935), Dutch botanist, independently discovers the laws of inheritance. Before publishing, he discovers Gregor Mendel's forgotten papers and his laws of heredity. He then announces Mendel's prior discovery and offers his own work only as confirmation. He propounds the idea of mutations in his *Die Mutationstheorie*, published in 1901.

1900 Boston Symphony Hall, the first structure designed according to the principles of acoustics, opens. These principles were discovered by American physicist Wallace Clement Sabine (1868– 1919) in 1895.

1900 First direct-arc electric furnace for producing steel is put into operation in France.

1901 Antoine Henri Becquerel (1852–1908), French physicist, studies the rays emitted by the natural substance uranium and concludes that the only place they could be coming from was within the atoms of uranium. This marks the first clear understanding of the atom as something more than a featureless sphere. It implies a dynamic reality that might also contain electrons. Becquerel's discovery of radioactivity and his focus on the uranium atom make him the father of modern atomic and nuclear physics.

1901 Jagadis Chnadra Bose (1858–1937), Indian physicist and plant physiologist, devises extremely sensitive instruments that are able to demonstrate the minute movements of plants to external stimuli and to measure their rate of growth. He pioneers what becomes biophysics and is also the first scientist from India to become internationally known.

1901 Jean Baptiste Perrin (1870–1942), French physicist, proposes the hypothesis that atoms are made up of a central nucleus around which electrons orbit like planets in a solar system.

1901 Josiah Willard Gibbs (1839–1903), American physicist, produces the concept of phase space using only the general laws of mechanics.

1901 National Bureau of Standards is first established in the United States.

1901 Pyotr Nicolaievich Lebedev (1866–1912), Russian physicist, uses extremely light mirrors in a vacuum and is able for the first time to measure the radiation pressure exerted by light. This also is an experimental confirmation of Maxwell's theory of electromagnetism.

1901 Wilhelm Konrad Röntgen (1845–1923), German physicist, receives the first Nobel Prize in Physics for his discovery of x rays.

1901 The work of David Bruce (1855–1931), Joseph Edward Dutton (1874–1905), and J.L. Todd, British bacteriologists, physicians, and researchers, results in the discovery of the parasite trypanosome, which causes African sleeping sickness.

1901 David Gill (1843–1914), Scottish astronomer, obtains the first accurate, modern determination of the sun's distance from Earth. Instead of using Venus or Mars as the point from which he makes his computations, he uses a prominent planetoid.

1901 Emil Adolf von Behring (1854–1917), German bacteriologist, becomes the first recipient of the Nobel Prize for physiology

or medicine. He is awarded for his work on serum therapy, especially its application against diphtheria.

1901 Eugène-Anatole Demarcy (1852–1904), French chemist, discovers the rare-earth element europium.

1901 François-Auguste Grignard (1871–1935), French chemist, discovers the highly useful catalytic role that organic manganese halides can play in preparing organic compounds. His work produces an entire series of what come to be known as "Grignard reagents."

1901 Frank Burnsey Taylor (1860–1938), American geologist, explains continental drift, saying that the mid-Atlantic ridge remained unmoved while the two continents on opposite sides moved in opposite directions.

1901 Gilbert Newton Lewis (1875–1946), American chemist, publishes an article in which he first defines the concept of fugacity (a measure of the tendency of a component of a liquid mixture to escape from the mixture).

1901 Hans Spemann (1869–1941), German embryologist, offers his first publication on embryonic induction. He eventually wins the Nobel Prize for showing that cells remain plastic very late into their development, and that they develop according to the nature of the neighboring area.

1901 Jacobus Henricus Van't Hoff (1852–1911), Dutch physical chemist, is awarded the Nobel Prize in chemistry for the discovery of the laws of chemical dynamics and osmotic pressure in solutions.

1901 Johann P.L. Elster (1854–1920) and Hans Geitel (1855–1923), German physicists, study the newly-discovered phenomenon of radioactivity and are the first to characterize it as being caused by changes that take place within the atom.

1901 Jokichi Takamine (1854–1922), Japanese-American chemist, and T.B. Aldrich first isolate epinephrine from the adrenal gland. It comes to be known by its trade name Adrenalin. It eventually is shown to be a neurotransmitter. This is also the first time a pure hormone has been isolated.

1901 Maurice Lugeon (1870–1953), Swiss geologist, extends to the Swiss Alps the interpretation of recumbent folding phenomena. This says that geologically older layers are found atop more recent ones. Lugeon's work pioneers the development of Alpine geology and offers the first comprehensive interpretation of the Alps as a whole.

1901 Rockefeller Institute founded.

1901 Rockefeller Institute for Medical Research opens.

1901 Santiago Ramòn y Cajal (1852–1911), Spanish histologist, first proves the true nature of the connection between nerves and shows that the nervous system consists of a maze of individual cells. He shows that the neurons do not touch, but that the signal somehow jumps a gap (now called a "synapse"). He also develops a staining technique still in use.

1901 William Bateson coins the terms "genetics," "F1 and F2 generations," "allelomorph" (later shortened to "allele"), "homozygote," "heterozygote," and "epistasis."

1901 Jules Bordet (1870–1961) and Octave Gengou (1875–1957) develop the complement fixation test.

1901 Guglielmo Marconi (1874–1937), Italian electrical engineer, successfully sends a radio signal from England to Newfoundland. This is the first transatlantic telegraphic radio transmission, and as such, is considered by most as the day radio is invented.

1902 Ernest Rutherford (1871–1937), British physicist, and Frederick Soddy (1877–1956), English chemist, publish a paper in which they offer a theory of disintegration of atoms as an explanation for radioactivity. They suggest that atoms break up and transform into other elements.

1902 Hendrik Antoon Lorentz (1853–1928) and Piter Zeeman (1865– 1943), Dutch physicists, win the Nobel Prize for physics for their discovery of the effect of magnetism on electromagnetic radiation.

1902 Josiah Willard Gibbs (1839–1903), American physicist, publishes his *Elementary Particles of Statistical Mechanics*, in

which he offers a rational formulation of thermodynamics.

1902 Oliver Heaviside (1850–1925), English physicist and electrical engineer, and Arthur Edwin Kennelly (1861–1939), British-American electrical engineer, independently and almost simultaneously make the first prediction of the existence of the ionosphere, an electrically conductive layer in the upper atmosphere that reflects radio waves. They theorize correctly that wireless telegraphy works over long distances because a conducting layer of the atmosphere exists that allows radio waves to follow Earth's curvature instead of traveling off into space.

1902 Alexis Carrel (1873–1944), French surgeon, first introduces his method of delicately sewing blood vessels together end-to-end.

1902 American Society of Clinical Surgeons is organized.

1902 Carl Schroter (1855–1939), German botanist, introduces the term "synecology," which is the study of the relations established among individuals of different species living in a given environment.

1902 Carnegie Institute founded.

1902 Charles-Robert Richet (1850–1935), French physiologist, and Paul-Jules Portier (1866–1962) introduce the term "anaphylaxis" to describe the violent and sometimes fatal reaction of a patient who is hypersensitive to an irritant.

1902 Clarence Erwin McClung (1870–1946), American zoologist, isolates the "x" or sex chromosome which is combined with a "y" chromosome in the male, as compared to two "x" chromosomes in the female.

1902 Ernest H. Starling (1866–1927) and William M. Bayliss (1860– 1924), both English physiologists, isolate and discover the first hormone ("secretin" found in the duodenum). Starling also first suggests a name for all substances discharged into the blood by a particular organ, and it is "hormones" from the Greek word meaning to "rouse to activity."

1902 Friedrich Otto Fritz Giesel (1852–1927), German chemist, first isolates element 89 on the periodic table—actinium.

1902 Georges Claude (1870–1960), French technologist, liquefies air.

1902 Harvey Cushing (1869–1939), American surgeon, performs the first nerve suture.

1902 Heber Doust Curtis (1872–1942), American astronomer, completes his doctorate, during which he studies nebulae, which he believes represent "island universes." His unpopular argument is based on the fact that there seem to be many more very faint novas than there ought to be if they were objects in our own galaxy. He is eventually proven correct.

1902 Hermann Emil Fischer (1852–1919), German chemist, is awarded the Nobel Prize in chemistry for his work on sugar and purine syntheses.

1902 Lórand Eotvos (1848–1919), Hungarian physicist, builds the first torsion balance for measuring gravity. His study of Earth's gravitational field, which led to his invention, results in the proof that inertial mass and gravitational mass are equivalent. This later becomes a major principle in Albert Einstein's general theory of relativity.

1902 Ronald Ross (1857–1932), English physician, is awarded the Nobel Prize for physiology or medicine for his work on malaria, showing how it enters the organism.

1902 Carl Neuberg introduces the term biochemistry.

1903 Antoine Henri Becquerel (1852–1908), French physicist, shares the Nobel Prize for physics with the husband-and-wife team of Marie Sklodowska Curie (1867–1934), Polish-French chemist, and Pierre Curie (1859–1906), French chemist. Becquerel wins for his discovery of natural or spontaneous radioactivity, and the Curies win for their later research on this new phenomenon.

1903 William Ramsay (1852–1916), Scottish chemist, and Frederick Soddy (1877–1956), English chemist, discover that helium is continually produced by naturally radioactive products.

1903 Albrecht Penck (1858–1945), German geologist, and Eduard Bruckner (1862–1927), German-Austrian geologist, publish the first of their three-volume *Die Alpen im Eiszeitalter*, in which they conclude there were four major glacial periods.

1903 Almroth Edward Wright (1861–1947), English bacteriologist, and his colleagues discover "opsonins" or antibodies in the blood of immunized animals.

1903 Archibald Edward Garrod (1857–1936), British physician, suggests that errors in genes lead to hereditary disorders. His 1909 book, *The Inborn Errors of Metabolism*, is the first study in biochemical genetics demonstrating that a single gene mutation blocks a single metabolic step.

1903 David Bruce (1855–1931), English bacteriologist, and David Nunes Nabarro (1874–1958), English physician, prove experimentally that the trypanosome causing sleeping sickness is introduced into humans by the bite of the tsetse fly.

1903 Emil Herman Fischer (1852–1919), German chemist, and Joseph von Mehring (1849–1908), German physician, introduce Veronal—a deliberate attempt to produce a reliable hypnotic. This barbiturate is known today as barbital.

1903 Emil Wiechert (1861–1928), German geologist, publishes his *Theorie der Automatischen Seismographen*, which becomes the basis of all later work on instrumental seismology.

1903 Ernest Rutherford (1871–1937), British physicist, and Frederick Soddy (1877–1956), English chemist, explain radioactivity by their theory of atomic disintegration. They discover that uranium breaks down and forms a new substance as it gives off radiation.

1903 Johan Herman Lie Vogt (1858–1932), Norwegian geologist, publishes *Die Silikat-Schmelzlosungen*, which pioneers the use of physical-chemical methods in the study of the origin of igneous rocks and ores. It also does much to stimulate quantitative research in this field.

1903 Mikhail Semenovich Tswett (1872–1919), Russian botanist, invents the technique of adsorption chromatography. It becomes a universally used method for separating and identifying organic substances.

1903 Niels Ryberg Finsen (1860–1904), Danish physician, pioneers light therapy and wins the Nobel Prize for physiology or medicine for his treatment of lupus by concentrated light rays.

1903 Rectoscopy is introduced into clinical use.

1903 Reginald Aldworth Daly (1871–1957), American-Canadian geologist, proposes his theory of magmatic stopping. This explains the structure of many igneous rock formations as it describes what occurs when molten magma rises through Earth's crust and shatters but does not melt the surrounding rocks. The rocks sink, being denser than the magma, which rises.

1903 Svante August Arrhenius (1859–1927), Swedish chemist, first uses the term "immunochemistry."

1903 Svante August Arrhenius (1859–1927), Swedish chemist, is awarded the Nobel Prize for chemistry for his electrolytic theory of dissociation.

1903 Walter S. Sutton (1876–1916) of the United States writes a short paper in which he states the chromosome theory of inheritance. This important idea that the hereditary factors are located in the chromosomes is also offered independently by Theodor Boveri (1862–1915) of Germany.

1903 Willem Einthoven (1860–1927), Dutch physiologist, invents the string galvanometer from which the electrocardiograph is derived.

1904 Bertram Borden Boltwood (1870–1927), American chemist and physicist, discovers that radium is a decay product of, or is descended from uranium, meaning that radioactive elements are not independent, but that one is descended from another, forming a radioactive series.

1904 Charles Glover Barkla (1877–1944), English physicist, discovers that x rays are transverse waves like those of light rather than longitudinal waves like those of sound.

1904 Hantaro Nagaoka (1865–1950), Japanese physicist, offers his mostly correct

Saturnian model of the atom, which says that there is a positively charged object at the atom's center around which electrons revolve (like Saturn's rings).

1904 Hendrik Antoon Lorentz (1853–1928), Dutch physicist, extends his idea of local time (different time rates in different locations) and arrives at what are called the Lorentz transformations. These are mathematical formulas describing the increase of mass, shortening of length, and dilation of time that are characteristic of a moving body. These eventually form the basis of Einstein's special theory of relativity.

1904 John William Strutt Rayleigh (1842–1919), English physicist, wins the Nobel Prize for physics for his investigations of the densities of the most important gases and for his discovery of argon.

1904 Ludwig Prandtl (1875–1953) of Germany discovers that as liquid flows in a tube, a film layer adjacent to the wall forms and does not flow as fast as the rest of the liquid. This is called a viscous boundary layer.

1904 *Journal of Experimental Zoology* is founded.

1904 Auguste-Alfred-Lucien-Gaston Lameere (1864–1942), Belgian zoologist, describes the law of allometric growth, which details the varying speeds of growth for different parts of the body that is characteristic of all animals.

1904 Charles Dillon Perrine (1867–1951), American-Argentinean astronomer, discovers the sixth satellite of Jupiter and the first of its outer satellites. He discovers the seventh satellite the following year.

1904 Emil G. Racovita (1868–1947), Romanian biologist, publishes the first findings dealing with animal populations that dwell in caves. His work founds modern biospeleology.

1904 Ernest-François-Auguste Fourneau (1872–1949), French chemist and pharmacologist, first synthesizes amylocaine. It is used eventually as a local anesthetic known as stovaine.

1904 Ernst Ferdinand Sauerbruch (1875–1951), Prussian surgeon, advances the possibilities for chest surgery with his invention of the pneumatic chamber at reduced atmospheric (negative) pressure, which prevents the lung from collapsing.

1904 First radical operation for prostatic cancer is performed by the American urologist Hugh Hampton Young (1870–1945).

1904 Frederic Stanley Kipping (1863–1949), English chemist, discovers silicones. It is his pioneering work on these complicated substances that leads to the post-war boom in the use of silicones as greases, water repellants, and synthetic rubbers.

1904 George Ellery Hale (1868–1938), American astronomer, proposes the foundation of an international group of solar researchers. The International Union for Cooperation in Solar Research comes out of his suggestion.

1904 Ivan Petrovich Pavlov (1849–1936), Russian physiologist, is awarded the Nobel Prize for physiology or medicine for his work establishing that the nervous system plays a part in controlling digestion and by helping to found gastroenterology.

1907 Ivan Petrovich Pavlov (1849–1936), Russian physiologist, investigates the conditioned reflex (1904–1907). His work stimulates behaviorist psychology and is the high point of physiologically-oriented psychology.

1904 Johannes Franz Hartmann (1865–1936), German astronomer, studies the spectrum of delta-Orionis and concludes that there is interstellar matter in the form of dust or gas. This is the first indication that matter exists in interstellar space.

1904 Joseph John Thomson (1856–1940), English physicist, formulates an atomic model and is one of the first to suggest a theory of structure of the atom (as a sphere of positive electricity in which negatively charged electrons are embedded).

1904 Paul Ehrlich (1854–1915), German bacteriologist, discovers a microbial dye called trypan red that helps destroy the trypanosomes (parasitic protozoa) that cause such diseases as sleeping sickness. This is the first such active agent against trypanosomes.

1904 Theodore William Richards (1868–1928), American chemist, improves Stas' method of determining atomic weights and revises some of his figures.

1904 Thomas Renton Elliott (1877–1961), English physician, suggests that nerve impulses in the brain could be transmitted chemically.

1904 Willia Ramsay (1852–1916), Scottish chemist, is awarded the Nobel Prize for chemistry for the discovery of the inert gaseous elements in air and his determination of their place in the periodic system.

1904 Lucien Claude Cuénot's crossbreeding experiments on mice provide proof that Mendel's newly rediscovered laws apply to animals as well as to plants. His research on the crossbreeding of yellow mice also provides the first example of genes that are lethal when homozygous. In 1910 other scientists prove that yellow homozygotes always die *in utero.*

1905 Hermann Walter Nernst (1864–1941), German physical chemist, announces his discovery of the third law of thermodynamics. He finds that entropy change approaches zero at a temperature of absolute zero, and deduces from this the impossibility of attaining absolute zero.

1905 Philipp Eduard Anton Lenard (1862–1947), Hungarian-German physicist, wins the Nobel Prize for physics for his work on cathode rays.

1905 William Weber Coblentz (1873–1962), American physicist, begins his career-long research on radiation beyond the visible spectrum. He demonstrates that compounds can be analyzed by the way they absorb infrared radiation. This is the principle behind the modern infrared spectrophotometer.

1905 Alfred Binet (1857–1911), French psychologist, devises the first of a series of tests (1905–1911) that make him the "father of intelligence testing."

1905 Alfred Einhorn (1856–1917), German chemist, discovers procaine (Novocaine), which becomes a local anesthetic.

1905 Alfred Werner (1866–1919), German-Swiss chemist, publishes *Neure Anschauungen*, which prepares the way for modern developments in inorganic chemistry and the electronic theory of valency.

1905 Daniel Moreau Barringer (1860–1929), American mining engineer and geologist, first proposes that the well-known, mile-wide crater in Arizona is not an extinct volcano but was formed by the impact of a large meteorite. Although this idea is derided, most evidence seems to indicate he is correct.

1905 Edmund Beecher Wilson (1856–1939), American zoologist, and Nettie M. Stevens (1861–1912) independently discover the connection between chromosomes and sex determination. They are the first to note the X and Y chromosomes.

1905 Ejnar Hertzsprung (1873–1967), Danish astronomer, first advances the notion of "absolute magnitude" for comparing the brightness of stars. He then goes on to note the important relationship between color and luminosity of stars.

1905 Harvey Williams Cushing (1869–1939), American neurosurgeon, begins his inventive, new brain operations and greatly advances the fields of neurosurgery and neurology.

1905 Jacobus Henricus Van't Hoff (1852–1911), Dutch-German physical chemist, publishes *Zur Bildung der Ozeanischen Salzablagerungen*, which is one of the first in-depth studies of the chemistry of marine deposits.

1905 Johann Friedrich Wilhelm von Baeyer (1835–1917), German chemist, is awarded the Nobel Prize for chemistry for his services in the advancement of organic chemistry and the chemical industry, through his work on organic dyes and hydroaromatic compounds.

1905 John Sydney Edkins (1863–1940), English physiologist, first describes gastric secretin ("gastrin").

1905 John Winter of England resuscitates a heart by the injection of epinephrine.

1905 Jules-Jean-Baptiste-Vincent Bordet (1870–1961), Belgian bacteriologist, and his colleague, Octave Gengou (1875–1957),

discover the bacillus of whooping cough (*B. pertussis*). Bordet goes on to discover a method of immunization against this dreaded childhood disease.

1905 Otto Folin (1867–1934), Swedish-American chemist, publishes his classic paper "Laws Governing Composition of Normal Urine," which helps explain the role of nitrogen and protein in human metabolism.

1905 Otto Hahn (1879–1968), German physical chemist, discovers radiothorium.

1905 Richard Willstatter (1872–1942), German chemist, discovers the structure of chlorophyll.

1905 Robert Koch (1843–1910), German bacteriologist, is awarded the Nobel Prize for physiology or medicine for his investigations and discoveries in relation to tuberculosis. He is one of the founders of the science of bacteriology.

1905 Standard Oil Company builds a 1,700-mile (2736-km) long pipeline between Kansas City and the west coast for the purpose of transporting up to 15,000 barrels of crude oil a day. The petroleum industry plans for expansion.

1905 Albert Einstein (1879–1955), German-Swiss-American physicist, uses Planck's theory to develop a quantum theory of light that explains the photoelectric effect. He suggests that light has a dual, wave-particle quality.

1905 Fritz Richard Schaudinn (1871–1906), German zoologist, discovers *Spirocheta pallida*, the organism or parasite causing syphilis. His discovery of this almost invisible parasite is due to his consummate technique and staining methods. This is a major step in controlling this disease.

1905 Albert Einstein (1879–1955), German-Swiss-American physicist, submits his first paper on the special theory of relativity titled "Zur Elektrodynamik bewegter Korpen." It states that the speed of light is constant for all conditions and that time is relative or passes at different rates for objects in constant relative motion. This is a fundamentally new and revolutionary way to look at the universe and it soon replaces the old Newtonian system.

1905 Albert Einstein (1879–1955), German-Swiss-American physicist, publishes his second paper on relativity in which he includes his famous equation stating the relationship between mass and energy: $E = mc^2$. In this equation, E is energy, m is mass, and c is the velocity of light. This contains the revolutionary concept that mass and energy are only different aspects of the same phenomenon.

1906 Charles Glover Barkla (1877–1944), English physicist, discovers that each particular element produces its own kind of ẋ rays. This breakthrough leads eventually to the fulfillment of the notion of atomic numbers

1906 Joseph John Thompson (1856–1940), English physicist, wins the Nobel Prize for physics for his theoretical and experimental investigations on the conduction of electricity by gases and for his discovery of the electron.

1906 Marie Sklodowska Curie (1867–1934), Polish-French chemist, assumes her husband Pierre's professorship at the Sorbonne after he is killed in a traffic accident. She becomes the first woman ever to teach there.

1906 Alfred Wilm of Germany discovers that aluminum-copper alloys can be hardened by aging. This breakthrough contributes to the increased recognition of the industrial applications of aluminum.

1906 Andrew Carnegie (1835–1919), American steel industrialist and philanthropist, finances the foundation of the Geophysical Laboratory in Washington, D.C.

1906 August von Wasserman (1866–1925), German bacteriologist, first develops a diagnostic blood test for syphilis.

1906 Camillo Golgi (1843–1926), Italian histologist, and Santiago Ramon y Cajal (1852–1934), Spanish anatomist, share the Nobel Prize for physiology or medicine for their work on the structure of the nervous system and the development of new staining techniques.

1906 Charles Sherrington (1857–1952), English neurologist, publishes his *Integrative*

Action of the Nervous System. In this work he develops a theory of reflex behavior of antagonistic muscles that helps to explain the way the body, guided and coordinated by its nervous system, acts as one or behaves as a unit.

1906 Ferdinand-Frédéric Henri Moissan (1852–1907), French chemist, is awarded the Nobel Prize for chemistry for his investigation and isolation of the element fluorine, and for the adoption in the service of science the electric furnace named after him.

1906 Frederick Gowland Hopkins (1861–1947), English biochemist, first argues that certain "accessory factors" in food are necessary to sustain life. This theory of trace substances becomes the starting point of further work on vitamin requirements.

1906 George Washington Crile (1864–1942), American surgeon, introduces direct arm-to-arm blood transfusion.

1906 Hermann Walther Nernst (1864–1941), German physical chemist, discovers what becomes known as the third law of thermodynamics, which states that entropy change approaches zero at a temperature of absolute zero. From this is deduced the impossibility of attaining absolute zero.

1906 Howard Taylor Ricketts (1871–1910), American pathologist, first proves that a certain wood tick transmits Rocky Mountain spotted fever.

1906 Jacobus Cornelius Kapteyn (1851–1922), Dutch astronomer, begins a survey of the Milky Way to count stars and to try to determine, from their numbers in various directions, the shape of the galaxy. He then describes a fairly small galaxy, which is lens-shaped and has the sun at its center. This model clashes with that proposed by Shapley, who later correctly describes a different galaxy of considerable proportions.

1906 Japan begins the production of monosodium glutamate (MSG) as a flavor-enhancer for foods. By 1926, production reaches industrial proportions.

1906 Karl Schwarzschild (1873–1916), German astronomer, suggests that energy in stellar atmospheres is transported mainly by radiation.

1906 Percival Lowell (1855–1916), American astronomer, begins a systematic search for a planet beyond Neptune that would account for the orbital peculiarities of Neptune and Uranus. This leads eventually to the discovery of Pluto.

1906 Richard Dixon Oldham (1858–1934), Irish geologist, supplies the first clear evidence that Earth has a central core. He becomes a pioneer in the application of seismology to the study of the interior of Earth.

1906 Stanton Abeles Friedberg (1875–1920), American surgeon, performs the first operation for the removal of a foreign body from the respiratory tract with the aid of bronchoscopy and esophagoscopy.

1906 IG Farbenindustrie, the largest European chemical industry of its time, is formed with the merger of BASF (Badische Anilin und Soda Fabrik), the Bayer Company, and the Agfa Company.

1906 Great San Francisco earthquake kills about 700 people and wrecks much of the city. Estimates of its force are about 8.3 on the Richter scale.

1906 Reginald Aubrey Fessenden (1866–1932), Canadian-American physicist, successfully transmits music and voice for the first time via radio waves that are picked up by wireless receivers. This becomes possible by his invention of the modulation of radio waves. This system sends out a continuous signal rather than a pulsed one, with the amplitude of the waves varied or modulated. These modulations are then sorted out, amplified, and reconverted into sound at the receiving end.

1907 Albert Abraham Michelson (1852–1931), German-American physicist, wins the Nobel Prize for physics for his optical precision instruments and the spectroscopic and meteorological investigations carried out with their aid.

1907 Hermann Minkowski (1864–1909), Russian-German mathematician, publishes his book *Time and Space*, in which he shows that Einstein's relativity theory

makes it necessary to regard time as a kind of fourth dimension.

1907 Pierre Weiss (1865–1940), French physicist, offers his theory explaining the phenomenon of ferromagnetism. He states that iron and other ferromagnetic materials form small "domains" of a certain polarity pointing in various directions. When some external magnetic field forces them to be aligned, they become a single, strong magnetic force. This explanation still applies.

1907 Adolf Windaus (1876–1959), German chemist, first synthesizes histamine. This important compound is found in animal tissues and has major physiological effects.

1907 Bertram Borden Boltwood (1870–1927), American chemist and physicist, discovers what he believes is a new element, which he calls ionium. It is later determined to be a radioactive isotope of thorium.

1907 Bertram Borden Boltwood (1870–1927), American chemist and physicist, first suggests how to determine the age of Earth's crust from the quantity of lead in uranium ores related to the known rate of uranium disintegration.

1907 Charles Franklin Craig (1872–1950), American physician, and Percy Moreau Ashburn (1872–1940, American surgeon, work in the Philippines and are the first to prove that dengue fever (also called "breakbone fever") is caused by a virus.

1907 Charles Horace Mayo (1865–1939), American surgeon, first uses the term "hyperthyroidism."

1907 Charles-Louis-Alphonse Laveran (1845–1922), French physician, is awarded the Nobel Prize for physiology or medicine for his work on the role played by protozoa in causing diseases.

1907 Clemens von Pirquet (1874–1929), Austrian physician, and Bela Schick (1877–1967), Austrian pediatrician, introduce the notion and term "allergy."

1907 Clemens von Pirquet (1874–1929), Austrian physician, first introduces the cutaneous or skin reaction test for the diagnosis of tuberculosis.

1907 Eduard Buchner (1860–1917), German chemist, is awarded the Nobel Prize for chemistry for his biochemical researches and his discovery of cell-free fermentation.

1907 Frederick Percival Mackie (1875–1944), English physician, discovers that the Asiatic relapsing fever is transmitted by the body louse.

1907 Georges Urbain (1872–1938), French chemist, discovers the last of the stable rare earth elements and names it lutetium after the village that stood in Roman times on the site where Paris is now.

1907 Karl Harry Ferdinand Rosenbusch (1836–1914), German geologist, publishes his *Mikroskopische Physiographie der Massigen Gesteine*, which contains a complete description of all the known magmatic rocks and outlines the practical means by which they can be identified according to the morphological, physical, and chemical properties of their component chemicals.

1907 Leo Hendrik Baekeland (1863–1944), Belgian-American chemist, produces synthetic resins on an industrial scale and creates Bakelite. This breakthrough is the first of the "thermosetting plastics," or plastics that once set will not soften under heat.

1907 Robert Emden (1862–1940), Swiss physicist and astrophysicist, publishes his *Gaskugeln*, which develops the physical theory of a gas sphere acted upon by its own gravity. This becomes an important work to the theory of stellar structure.

1907 Ross Granville Harrison (1870–1959), American zoologist, develops the first successful animal-tissue culture and pioneers organ transplant techniques. His cultivation of tadpole tissue is the first culture "in vitro" of animal cells.

1908 Ernest Rutherford (1871–1937), British physicist, and Hans Wilhelm Geiger (1882–1945), German physicist, invent an electrical alpha-particle counter. Over the next few years, Geiger continues to improve this device, which becomes known as the Geiger counter.

1908 Gabriel Lippmann (1845–1921), French physicist, wins the Nobel Prize for physics

for reproducing colors photographically based on the phenomenon of interference. He invents the first method of color photography.

1908 Heike Kamerlingh Onnes (1853–1926), Dutch physicist, produces liquid helium for the first time. This leads to further discoveries.

1908 Jean Baptiste Perrin (1870–1942), French physicist, uses Einstein's formula for Brownian motion and, by actually counting the distribution of suspended particles of gum resin in a liquid, finds that he can, for the first time, calculate the approximate size of atoms and molecules by observation. This is the final proof that atoms are real entities and not just convenient fictions.

1908 Percy Williams Bridgman (1882–1961), American physicist, begins a lifetime of pioneering work in the field of high pressures. Working eventually in the unexplored field of attaining 400,000 atmospheres, he is forced to invent much of his equipment himself. As he extends the range of pressures, he becomes the founder of the laws of high pressure physics.

1908 A 60-inch (1.5-m) reflecting telescope is built on Mount Wilson, near Pasadena, California. It is planned and organized by American astronomer George Ellery Hale (1868–1938) and paid for by the American steel industrialist Andrew Carnegie (1835–1919).

1908 Arthur Nicolaier (1862–1942), German physician and bacteriologist, and R. Dorn introduce phenylcinconimic acid (cinchophen), a diuretic that becomes a successful anti-rheumatic and anti-gout medicine.

1908 Bela Schick (1877–1967), Hungarian pediatrician, devises the first skin test to determine a patient's susceptibility to diphtheria.

1908 Ernest Rutherford (1871–1937), English physicist, is awarded the Nobel Prize for chemistry for his investigations into the disintegration of the elements and the chemistry of radioactive substances.

1908 Frank Wigglesworth Clarke (1847–1931), American chemist and geophysicist, publishes *The Data of Geochemistry*, in which he unites all the chemical analyses of rocks carried out in the laboratories of the U.S. Geological Survey. Clarke is also the first to estimate the average chemical composition of Earth's crust.

1908 Fritz Haber (1868–1934), German chemist, first synthesizes ammonia. Using iron as a catalyst, he combines nitrogen and hydrogen under pressure and forms ammonia. Using this method, which became known as the Haber process, he is able to fix nitrogen and potentially create plentiful supplies of it for fertilizer or explosives.

1908 G. Ghedini, Italian physician, introduces the biopsy of bone marrow as a clinical procedure. He obtains the marrow by puncturing the shaft of the tibia.

1908 George Ellery Hale (1868–1938), American astronomer, first detects the magnetic field of an extraterrestrial body as he locates strong magnetic fields inside sunspots. This is also called the Zeeman effect.

1908 Godfrey Harold Hardy (1877–1947), English mathematician, and German physician Wilhelm Weinberg (1862–1937) publish similar papers (six months apart) on a mathematical system that describes the stability of gene frequencies in succeeding generations of a population. Their resulting "Hardy-Weiberg Law" links the Mendelian hypothesis with actual population studies.

1908 Henrietta Swan Leavitt (1868–1921), American astronomer, concludes from a study of variable stars that there exists a correlation between their period and absolute magnitudes, with the brighter stars having longer periods.

1908 Ilya Ilich Mechnikov (1845–1916), Russian-French bacteriologist, and Paul Ehrlich (1854–1915), German bacteriologist, are awarded the Nobel Prize for Physiology or Medicine for their work on the theory and principles of disease immunity.

1908 Margaret Lewis (1881–1970), American cytologist, first cultures mammalian cells in vitro.

1908 Reuben Ottenberg, American physician, reports the first transfusion in which bloods tests for compatibility are done.

1908 The egg parasite of the gypsy moth is first introduced into the United States from Japan. In its caterpillar stage, the insect is responsible for considerable defoliation.

1908 William Ramsay (1852–1916), Scottish chemist, puts forward the electronic theory of valency.

1908 George H. Shull (1874–1954) proposes using self-fertilized lines in the production of commercial seed corn. This results in highly successful hybrid corn programs.

1908 Nilsson H. Ehle proposes the multiple-factor hypothesis to explain the quantitative inheritance of seed-coat color in wheat.

1908 The Siberian "meteorite" falls in the Tunguska region of Siberia. An explosive impact or detonation is heard over a distance of 621.4 miles (1,000 km), and millions of trees are flattened. The first expedition to this uninhabited area finds no traces of a meteorite, and the cause of this incredibly powerful explosion is the focus of much speculation. Some think it was the icy nucleus of a small comet, while others speculate it may have been an impact with a small black hole.

1909 Constantin Caratheodory (1873–1950), German mathematician, publishes the first axiomatic theory of thermodynamics, that is, the first theory that is not linked to the cycles of heat machines.

1909 Guglielmo Marconi (1874–1937), Italian electrical engineer, and Karl Ferdinand Braun (1850–1918), German physicist, win the Nobel Prize for their contributions to the development of wireless telegraphy.

1909 Hendrik Anton Lorentz (1853–1928), publishes *The Theory of Electrons and its Applications to the Phenomena of Light and Radiant Heat*, in which he perfects electrodynamics and the electron theory.

1909 Alfred Stock (1876–1946), German chemist, first synthesizes boron hydrides (compounds of boron and hydrogen). Forty years later, boron hydrides prove useful to space exploration as additives to rocket fuel.

1909 Andrija Mohorovičić (1857–1936), Croatian geologist, studies earthquake wave patterns and deduces that Earth possesses a layered structure. He states that the separation between the top two layers is not gradual but sharp and lies from ten to forty miles below sea level. This separation is called the Mohorovičić discontinuity.

1909 Benjamin Minge Duggar (1872–1956), American botanist, publishes his *Fungous Diseases of Plants*, the first text to be published on this subject.

1909 Bernard Aschner (1883–1960), German pathologist, shows that hypophysectomy (excision of the pituitary gland) in a growing animal causes dwarfism.

1909 Charles J.H. Nicolle (1866–1936), French bacteriologist, discovers how exanthematic typhus is transmitted (by the body louse).

1909 David Marine (c.1880–1976), American pathologist, proves that iodine is necessary for thyroid function.

1909 Emil Theodor Kocher (1841–1917), Swiss surgeon and endocrinologist, is awarded the Nobel Prize for physiology or medicine for his work on the physiology, pathology, and surgery of the thyroid gland.

1909 Esper Signius Larsen (1879–1961), American petrologist, and Frederic Eugene Wright (1877–1953), American geologist, publish a joint paper that is one of the earliest systematic efforts to establish criteria for geological thermometry. They use quartz as a geological thermometer.

1909 Friedrich Wilhelm Ostwald (1853–1932), Russian-German physical chemist, is awarded the Nobel Prize for chemistry for his work on catalysis and for his investigations into the fundamental principles governing chemical equilibria and rates of reaction.

1909 Jean de Mayer, French physiologist, first suggests the name "insuline" for the hormone of the islet cells.

1909 Johann Paul Karplus (1866–1936) and Alois Kreidl (1864–1928), both Austrian physiologists, report on the first experimental studies on the hypothalamus.

1909 Karl Landsteiner (1868–1943), American pathologist, and Romanian bacteriologist Constantin Levaditi (1874–1953) succeed in transmitting poliomyelitis to monkeys.

1909 Korbinian Brodmann (1868–1918), German neurologist, publishes a "map" of the brain's cerebral cortex that assigns numbers to its different regions.

1909 N. Pierantoni begins the first studies of the mechanism of symbiosis between animals and microorganisms. His research introduces the notion that ecologically, all animals can be considered a part of the environment.

1909 Phoebus Aaron Theodore Levene (1869–1940), Russian-American chemist, discovers the chemical distinction between DNA (deoxyribonucleic acid) and RNA (ribonucleic acid).

1909 Soren Peter Lauritz Sorensen (1868–1939), Danish chemist, first introduces the expression pH to denote the negative logarithm of the concentration of the hydrogen ion present. It becomes a standard measure of alkalinity and acidity.

1909 Thomas Hunt Morgan (1866–1945), American geneticist, chooses the fruit fly *Drosophila* as a means of investigating genetics with the aid of mutations. He demonstrates the chromosome theory of heredity and perceives the significance of the tendency of certain genes to be transmitted together. He postulates "crossing over," which is demonstrated by Sturtevant in 1913.

1909 Walter Reed General Hospital opens in Washington, D.C.

1909 Wilhelm Ludwig Johannsen (1857–1927), Danish botanist, first offers the terms "gene" (the carrier of heredity), "genotype" (the genetic constitution of an organism), and "phenotype" (the actual organism that is their product).

1909 Willis D. Gatch, American surgeon, invents a surgical bed with an adjustable steel frame for supporting the patient in a sitting or a semi-sitting posture for postoperative care.

1909 Sigurd Orla-Jensen proposes that the physiological reactions of bacteria are primarily important in their classification.

1910 Johannes Diderik Van der Waals (1837–1923), Dutch physicist, wins the Nobel Prize for physics for his work on the equation of state for gases and liquids.

1910 Joseph John Thomson (1856–1940), English physicist, measures deflections of positive rays in a cathode tube and calculates the masses of various atoms. He discovers that neon has two isotopes. This is the first confirmation that isotopes are possible, as predicted by English chemist Frederick Soddy (1877–1956).

1910 William Henry Bragg (1862–1942), English physicist, discovers the role of x rays and gamma rays in causing rarified gases to conduct electricity. This happens because the rays knock the electrons out of the gas molecules. He also notes that in this process, both types of rays behave like particles.

1910 Albrecht Kossel (1853–1927), German biochemist, is awarded the Nobel Prize for physiology or medicine for his outstanding discoveries in the chemistry of the cell and the cell nucleus, achieved through his work on proteins, including nucleic substances.

1910 Charles Schuchert (1858–1942), American paleontologist, publishes his article "Paleography of North America," which contains his principles of paleogeography. This pioneering work makes him a leader in this field, which is the study of the distribution of lands and seas in the geological past.

1910 Charles J.H. Nicolle (1866–1936), French bacteriologist, discovers the viral origin of influenza.

1910 Edward Bright Vedder (1878–1952), American physician, first discovers the ability of emetine to kill the amoeba that causes amebic dysentery. Emetine is a crystalline alkaloid extracted from the ipecac root.

1910 Emanuel Libman (1872–1946), American physician, publishes the first (and now classic) description of bacterial endocarditis or inflammation of the heart's lining.

1910 The Flexner Report on U.S. medical education is released. Led by American educator Abraham Flexner (1866–1959), this report rates the 155 medical schools in the

United States and Canada and has a major impact on the role of science in the U.S. educational system.

1910 Francis Peyton Rous (1879–1970), American pathologist, experiments with transmitting sarcomas in hens and discovers the first cancer-inducing viruses.

1910 Halley's Comet makes its predicted return past Earth and causes a sensation.

1910 Harvey Cushing (1869–1939), American surgeon, and his team present the first experimental evidence of the link between the anterior pituitary and the reproductive organs.

1910 Isador Henry Coriat (1875–1943), American psychiatrist and neurologist, publishes his *Abnormal Psychology*, the first systematic treatment in English of this subject.

1910 James Bryan Herrick (1861–1954), American physician, first describes sickle-cell anemia, a disease caused by a congenital anomaly in the blood that appears mostly in those of African descent.

1910 Jean-Eugène Bataillon (1864–1953), French biologist and zoologist, achieves parthenogenesis (artificial fertilization) in invertebrates (frog's eggs).

1910 Otto Wallach (1847–1931), German organic chemist, is awarded the Nobel Prize for chemistry for his services to organic chemistry and the chemical industry by his pioneering work in the field of alicyclic compounds.

1910 Paul Ehrlich (1854–1915), German bacteriologist, announces his discovery of an effective chemical treatment for syphilis. He names this new drug Salvarsan, and it is now called arsphenamine. His discovery marks the beginning of modern chemotherapy.

1910 The Smithsonian Institution sponsors a biological survey of the Canal Zone in Panama before any digging begins.

1910 William Henry Howell (1860–1945), American physiologist, offers the first model of blood coagulation. This proves especially significant when transfusions become more commonplace during World War I.

1911 First congress of physicists is sponsored by Belgian chemist Ernest Solvay (1838–1922). It is held in Brussels, Belgium, and its subjects are radiation theory and quanta.

1911 Heike Kamerlingh Onnes (1853–1926), Dutch physicist, first discovers the phenomenon of superconductivity, when he studies the properties of certain metals subjected to the low temperatures of liquid helium. He finds that some metals, like mercury and lead, undergo a total loss of electrical resistance. He also discovers that a form of liquid helium called "helium II" is produced, which has properties unlike any other substance.

1911 Owen Willans Richardson (1879–1959), English physicist, studies how electrons and ions are given off by heated metals and works out the theory of electron and ion emission. This is called the Edison effect and later makes possible the vacuum tube.

1911 Wilhelm Wien (1864–1928), German physicist, wins the Nobel Prize for physics for his discoveries regarding the laws governing the radiation of heat (black bodies).

1911 Allvar Gullstrand (1862–1930), Swedish physician, is awarded the Nobel Prize for physiology or medicine for his mathematical and physical studies of dioptrics or the science of the refraction of light through the transparent media of the living eye.

1911 Casimir Funk (1884–1967), Polish-American biochemist, demonstrates the dietary cause of beriberi (lack of thiamine, or vitamin B_1.

1911 Chaim Weizmann (1874–1952), Russian-English-Israeli chemist, discovers how to use the bacteria from fermenting grain to synthesize acetone. Acetone is essential to the production of the explosive cordite.

1911 Charles Greely Abbott (1872–1961), American astronomer, publishes *The Sun*, an authoritative work in which he suggests that the sun is gaseous throughout.

1911 Ernest Rutherford (1871–1937), British physicist, discovers that atoms are made up of a positive nucleus surrounded by

electrons. This modern concept of the atom replaces the notion of featureless, indivisible spheres, which dominated atomistic thinking for 23 centuries—since Democritus.

1911 Fritz Pregl (1869–1930), Austrian chemist, first introduces organic microanalysis. He invents analytic methods that make it possible to determine the empirical formula of an organic compound from just a few milligrams of the substance.

1911 Harry Fielding Reid (1859–1944), American geophysicist, publishes his article "The Elastic-Rebound Theory of Earthquakes." He proposes that faults are preexisting and are not breaks in the crust caused by earthquakes. He also says that pressures along the fault increase until there is a sudden slippage of one fault side against the other, causing vibrations and thus quake effects. His ideas are still accepted.

1911 Hideyo Noguchi (1876–1928), Japanese bacteriologist, first introduces the luetin or skin test for syphilis.

1911 Marie Sklodowska-Curie (1867–1934), Polish-French chemist, is awarded the Nobel Prize for chemistry for the discovery of the elements radium and polonium, the isolation of radium, and the study of the nature and compounds of this element.

1911 R.A. Lambert and F.M. Hanes perform the first successful in vitro cultivation of tumoral cells. This technique proves very useful in the advancement of oncological research.

1911 Russell A. Hibbs (1869–1932), American surgeon, first introduces the spinal fusion operation. His technique of removing the cartilage and periosteum of adjacent vertebral parts allows for the fusion of a diseased or fractured spine.

1911 The first sheets of cellophane are produced.

1911 The state of New Jersey passes a law requiring segregation of the "careless consumptive."

1911 Victor Franz Hess (1883–1964), Austrian-American physicist, begins a series of experimental balloon ascents and proves that an extremely penetrating radiation that does not originate in the sun actually permeates the atmosphere.

1911 Viktor Moritz Goldschmidt (1888–1947), Swiss-Norwegian geochemist, publishes *Die Kontaktmetamorphose im Kristiania-Gebiete*, in which he makes extensive studies of the alteration of rocks by heat and makes several fundamental advances in correlating the mineralogical and chemical composition of metamorphic rocks. He is recognized as the founder of modern geochemistry and crystal chemistry.

1911 William Morton Wheeler (1865–1937), American zoologist, publishes *The Ant Colony as an Organism*, which examines for the first time the close correlation that exists between an organized colony of animals and a multicellular organism made up of cells.

1911 Ernest Rutherford (1871–1937), British physicist, presents his theory of the nuclear atom, saying that the atom consists of a very small, positively charged nucleus surrounded by negatively charged electrons. With this, he lays the foundation for the development of nuclear physics.

1912 Dmitry Sergeevich Rozhdestvenski (1876–1940) elaborates an extremely sensitive method for measuring the intensity of spectral lines. This study of spectra offers a valuable experimental basis for research on the atom.

1912 Karl Frithiof Sundman (1873–1949), Finnish astronomer, publishes his "Memoire sur le probleme des trois corps," in which he offers a theoretical solution to the long-unsolved three-body problem.

1912 Nils Gustaf Dalen (1869–1937) of Sweden wins the Nobel Prize for physics for his invention of automatic regulators for use in conjunction with gas accumulators for illuminating lighthouses and buoys.

1912 Owen Willans Richardson (1879–1959), English physicist, and Arthur Holly Compton (1892–1962), American physicist, confirm the validity of Einstein's hypothesis on the quantization of interactions between radiation and matter.

1912 A. Leowe discovers phenobarbital, known as Luminal. It has an antiepileptic effect.

1912 Alexis Carrel (1873–1944), French-American surgeon, is awarded the Nobel Prize for physiology or medicine for his work on vascular suture and the transplantation of blood vessels and organs.

1912 Alexis Carrel (1873–1944), French-American surgeon, succeeds in producing the first true cell culture (chick embryo fibroblasts). Since he is able to keep tissue alive, his research allows for the development of cells to be followed.

1912 American Medical Association amends its 1846 Epidemic Code of Ethics and now allows a physician to refuse a patient except under emergency conditions.

1912 Casimir Funk (1884–1967), Polish-American biochemist, coins the word "vitamine." Since the dietary substances he discovers are in the amine group, he calls all of them "life-amines" or "vitamines."

1912 Edouard Claparède (1873–1940), Swiss psychologist, founds the Institut J.-J. Rousseau in Geneva, a school whose functional psychology measures the intelligence of students.

1912 Elmer Verner McCollum (1879–1967) and Marguerite Davis (1887–1967), both American chemists, discover vitamin A in butter and egg yolk. It is discovered at the same time by American biochemist Thomas Burr Osborne (1859–1929) and Lafayette Benedict Mendel (1872–1935), an American physical chemist, but McCollum and Davis publish first.

1912 First chair in Biochemistry in the United Kingdom goes to Frederick Gowland Hopkins (1861–1947) at Cambridge University.

1912 François-Auguste-Victor Grignard (1871–1935), French chemist, is awarded the Nobel Prize for chemistry for the discovery of the so-called Grignard reagent, which greatly advanced the progress of organic chemistry. Paul Sabatier (1854–1941), French chemist, is also awarded the Nobel Prize for chemistry for his method of hydrogenating organic compounds in the presence of finely disintegrated metals.

1912 Friedrich A. Paneth (1887–1958), German-British chemist, and Georg von Hevesy (1885–1966), Hungarian-born chemist, first use radioactive indicators experimentally in living systems.

1912 Friedrich Karl Rudolph Bergius (1884–1949), German chemist, discovers how to treat coal and oil with hydrogen to produce gasoline.

1912 Henrietta Swan Leavitt (1868–1921), American astronomer, is able to calculate the true distance of the far-off stars in the Magellanic clouds and thus contributes to an understanding of the vast size of the universe. This is called the Cepheid method of measuring distances, because the faraway stars she measures are in the constellation Cepheus.

1912 James Bryan Herrick (1861–1954), American physician, first describes a myocardial infarction, commonly known as a heart attack.

1912 Max Theodor Felix von Laue (1879–1960), German physicist, develops x-ray crystallography. After refracting x rays with a crystal of zinc sulfide, he identifies their transverse nature. With this technique, he then measures the wavelengths of x rays and studies the atomic structure of crystals.

1912 Max Theodor Felix von Laue (1879–1960), German physicist, obtains a diffraction pattern for x rays through a crystal and offers evidence that x rays are a form of electromagnetic radiation and are waves. This marks the beginning of studies on the physics of solids as an analysis of the periodic and regular disposition of atoms in a crystal.

1912 Vesto Melvin Slipher (1875–1969), American astronomer, is the first to study the spectrum of the Andromeda nebula and to measure the relative velocity of a nebula. He determines that it is approaching rather than receding from Earth and calculates its speed at 125 miles per second. He later determines that nearly all other nebulae are receding from Earth.

1912 Vesto Melvin Slipher (1875–1969) and Percival Lowell (1855– 1916), both American

astronomers, determine the period of rotation of Venus.

1912 The United States Public Health Service is established.

1912 Victor Franz Hess (1883–1964), Austrian-American physicist, demonstrates that the amount of radiation reaching Earth is not affected by an eclipse that occurs on this date. He says this radiation does not come from the sun and calls it "altitude rays." He has discovered what become known as cosmic rays.

1912 Walter Friedrich (1883–1968), German physicist, and Paul Knipping make the first experimental observations of the diffusion of x rays by crystalline structures. Their work demonstrates the electromagnetic nature of x rays.

1913 Charles Fabry (1867–1945), French physicist, first demonstrates the presence of ozone in the upper atmosphere. The importance of ozone is now known to be a screen of most of the sun's ultraviolet radiation. Seventy-five years after this discovery, a "hole" in the ozone layer over Antarctica is discovered via satellite.

1913 Hans Wilhelm Geiger (1882–1945), German physicist, develops and improves his original device for detecting energetic subatomic particles called the Geiger counter. In 1928 he collaborates with Walther Muller and produces a more sensitive instrument that has a longer lifetime, known as the Geiger-Muller counter.

1913 Heike Kamerlingh Onnes (1853–1926), Dutch physicist, wins the Nobel Prize for physics for his investigations on the properties of matter at low temperatures, which lead to the production of liquid helium.

1913 Henry Gwyn-Jeffreys Moseley (1887–1915), English physicist, discovers that the characteristic wavelength x rays of over fifty elements he examines all decrease regularly as their atomic weight increases. He then discovers that this means that a particular element has the same number of electrons as its atomic number, and that arranging them by atomic number would give scientists, for the first time, foreknowledge of how many elements remain to be discovered.

1913 Johannes Stark (1874–1957), German physicist, demonstrates that a strong electric field causes a multiplication or splitting of spectral lines. Called the Stark effect, this phenomenon is analogous to the effect of a magnetic field and eventually becomes supportive of the quantum theory.

1913 Niles Henrik David Bohr (1885–1962), Danish physicist, offers an entirely different theoretical model for the hydrogen atom. Searching to understand how an atom radiates light, he incorporates Planck's quantum postulate and states that electrons orbit the nucleus in fixed orbits, giving off quanta when jumping from one orbit to another. This is the first reasonably successful attempt to explain the internal structure of the atom via spectroscopy (as well as explain spectroscopy by that structure).

1913 Robert Andrews Millikan (1868–1953), American physicist, conducts his famous "oil drop" experiment and determines the value of the electric charge of a single electron. He allows a tiny drop of oil to be charged electrically while dropping it under the influence of gravity. By balancing the effects of the electromagnetic attraction and the gravitational attraction downward both before and after, he can calculate the charge of a single electron.

1913 A. Knauer describes the psychotropic action of mescaline, a hallucinogen known to the Aztecs.

1913 Alfred Henry Sturtevant (1891–1970), American geneticist, produces the first chromosome map, showing five sex-linked genes.

1913 Alfred Werner (1866–1919), German-Swiss chemist, is awarded the Nobel prize for chemistry for his work on the linkage of atoms in molecules by which he opened up new fields of research, especially in inorganic chemistry.

1913 American College of Surgeons is founded.

1913 Beno Gutenberg (1889–1960), German-American geologist, postulates the existence of a liquid core at the center of Earth

that has a radius of about 2,100 miles. The sharp boundary between the core and the rocky mantle above it is later called the Gutenberg discontinuity.

1913 Charles-Robert Richet (1850–1935), French physiologist, is awarded the Nobel Prize for physiology or medicine for his work on anaphylaxis (hypersensitivity to foreign substances in the body).

1913 Ejnar Hertzsprung (1873–1967), Danish astronomer, and Harlow Shapley (1885–1972), American astronomer, are the first to prove the existence of star systems outside the Milky Way.

1913 Elmer Verner McCollum (1879–1967), American biochemist, discovers that a factor essential to life is present in water-soluble fats; it is soon named vitamin A.

1913 First use in the United States of chlorination to purify water.

1913 Friedrich Johann Karl Becke (1855–1931), German mineralogist, offers the first comprehensive theory of metamorphic rocks.

1913 Gustave Roussy (1874–1948) and J. Camus produce experimental diabetes insipidus (DI) in dogs by injury to the hypothalamus.

1913 Henry Gwyn-Jeffreys Moseley (1887–1915), English physicist, studies the x ray frequency characteristics of the various elements and discovers a technique to determine the atomic number of the nucleus. He finds that the positive charge of the nucleus indicates the number of electrons present in every neutral atom.

1913 Jean-Baptiste Perrin (1870–1942), French physicist, publishes *Les Atomes*, in which he offers systematically-obtained evidence of the size and number of atoms and molecules in a given volume of gum resin. For the first time, science has real evidence through observation of the existence of these tiny entities.

1913 Johannes Andreas Grib Fibiger (1867–1928), Danish pathologist, produces the first nonviral tumor in a laboratory experiment on rats. This shows that cancers can arise from an external (e.g., chemical) source.

1913 Leonor Michaelis (1875–1949), German-American scientist, works out an equation that describes how the rate of an enzyme-catalyzed reaction varies with the concentration of the substance taking part in the reaction. It is called the Michaelis-Menten equation after him and his assistant.

1913 M.J. Trumble of the United States first introduces the pipe still into the distillation of petroleum.

1913 Maud Slye (1879–1954), American pathologist, begins selective mice-breeding experiments focusing on hereditary susceptibility to and immunity from cancer.

1913 Max Bodenstein (1871–1942), German physical chemist, develops the concept of a chain reaction, in which one molecular change triggers the next, and so on.

1913 Niels Henrik David Bohr (1885–1962), Danish physicist, proposes the first dynamic model of the atom. It is seen as a very dense nucleus surrounded by electrons rotating in stationary elliptical orbits.

1913 Plant quarantines are first imposed in the United States on a national basis.

1913 Pleuroscopy (also known as thoracoscopy) is introduced for clinical use in examining the thoracic area.

1913 Willem de Sitter (1872–1934), Dutch astronomer, analyzes the movements of a binary star and supports Einstein's theory of the constancy of the speed of light. He says that binary stars would show some sort of anomaly (which they do not) if the speed of light depended on the speed of the light source.

1913 William Henry Bragg (1862–1942), English physicist, and his son William Lawrence Bragg (1890–1971), Australian-English physicist, develop the x ray spectrometer, which is basic to their determination of crystal structure.

1913 William Lawrence Bragg (1890–1971), Australian-English physicist, and his father William Henry Bragg (1862–1942), make the first determinations of the structures of simple crystals and demonstrate the tetrahedral distribution of carbon atoms in diamonds.

1913 Calvin Blackman Bridges (1889–1938) discovers evidence of nondisjunction of the sex chromosomes in the fruit fly *Drosophila*. This evidence later helps support Thomas H. Morgan's (1866–1945) new chromosome theory of heredity.

1913 Frederick Soddy (1877–1956), English chemist, introduces the term and the concept of "isotope" for atoms of the same element that have different atomic masses. He suggests that different elements produced in radioactive transformations are capable of occupying the same place in the periodic table. He chooses the Greek words meaning "same place" to describe them.

1914 Ernest Rutherford (1871–1937), British physicist, discovers a positively charged particle he later calls a proton.

1914 James Franck (1882–1964), German-American physicist, and the German physicist Gustav Hertz (1887–1975) bombard gases and vapors with electrons of different energies and arrive at an experimental confirmation of the Bohr model of the atom.

1914 Max Theodore Felix von Laue (1879–1960), German physicist, wins the Nobel Prize for physics for his discovery of the diffraction of x rays by crystals.

1914 Chaim Weizmann (1874–1952), Russian-English-Israeli chemist, invents the industrial process of butyl acetone fermentation. Acetone becomes essential to the production of explosives during World War I.

1914 Edward Calvin Kendall (1886–1972), American biochemist, extracts thyroxin from the thyroid gland (isolating thyroxine in crystalline form) and founds hormonology. In 1919 he also produces pure thyroxine.

1914 Ernest Henry Starling (1866–1927), English physiologist, experimentally establishes the law according to which the heart's muscles contract with a force proportional to the distension of its fibers during diastole (filled with blood).

1914 First electric induction furnace for the industrial production of steel is installed in Pennsylvania.

1914 Henry Hallett Dale (1875–1968), English biologist, first isolates acetylcholine—a substance that will prove crucial to the discovery of the chemical transmission of nerve impulses.

1914 Henry Norris Russell (1877–1957), American astronomer, studies the relationship between the brightness of stars and their color and spectral class. He then plots a diagonal line for their comparative luminosity and says that this implies a definite life cycle that stars follow. Although his theory is overly simple, it is the first good attempt at working out the evolutionary life cycle of stars.

1914 John Broadus Watson (1878–1958), American psychologist, founds the behaviorist school of psychology. He publishes his book *Behaviorism: An Introduction to Comparative Psychology*, which states that human behavior is explainable in terms of conditioned responses.

1914 Joseph Barrell (1869–1919), American geologist, writes an article in which he introduces the terms "lithosphere" and "asthenosphere."

1914 Kaiser-Wilhelm Institute for Biology is founded in Berlin, Germany.

1914 Louis Anatole La Garde (1849–1920), American surgeon, publishes *Gunshot Injuries*, a work that becomes a classic study in the history of ballistics wounds. He demonstrates that bullet wounds are not sterile, and that contrary to the view that the heat of the bullet destroys microorganisms, they are actually conveyed directly into the wound.

1914 Morris Simmonds (1855–1925), German physician, first describes pituitary cachexia or atrophy (named Simmonds' disease).

1914 Pasteurization of milk begins in many large cities.

1914 Paul Ernst Christof Buchner, German zoologist, discovers the mechanism of bioluminescence in marine animals, demonstrating that it is the result of a symbiosis with bacteria, within which typical chemical reactions occur.

1914 Robert Barany (1876–1936), Austrian physician, is awarded the Nobel Prize for

physiology or medicine for first devising a number of tests that can diagnose vestibular (inner ear) problems like vertigo.

1914 Seth Barnes Nicholson (1891–1963), American astronomer, discovers a satellite of Jupiter. During his career he discovers four altogether.

1914 Theodore William Richards (1868–1928), American chemist, is awarded the Nobel Prize for chemistry for his accurate determination of the atomic weight of a large number of chemical elements.

1914 Walter Sydney Adams (1876–1956), American astronomer, proves that from the spectra alone, it is possible to tell whether a star is a giant or a dwarf. He also is able to deduce a star's luminosity from its spectrum.

1915 William Henry Bragg (1862–1942) and William Lawrence Bragg (1890–1971), father-and-son English physicists, win the Nobel Prize for physics for their services in the analysis of crystal structure by means of x rays.

1915 Alfred Lothar Wegener (1880–1930), German geologist, publishes *Die Entstehung der Kontinente und Ozeane*, which offers geology the revolutionary theory of continents in motion. The continents were originally part of a single landmass he says, which slowly drifted apart. This did not occur suddenly or catastrophically but was and is a gradual, continuous process. However, he cannot offer a mechanism accounting for this movement.

1915 Death certificates come into general use.

1915 Frederick William Twort (1877–1950), English bacteriologist, and Felix H. d'Herelle (1873–1949), Canadian-Russian physician, independently discover the existence of bacteriophage, viruses that destroy bacteria.

1915 Harry Plotz (1890–1947), American bacteriologist, discovers the typhus organism.

c. 1915 Keith Lucas (1879–1916), British psychologist, first demonstrates the "all or none" response of stimulated neurons. This principle will eventually be recalled when the digital computer is invented later in the century, and its binary (0 or 1) system will contribute to the notion of the brain as a computer (and the computer as a brain).

1915 Mayo Foundation for Medical Education and Research is founded in Rochester, Minnesota.

1915 Richard Martin Willstatter (1872–1942), German chemist, is awarded the Nobel Prize for chemistry for his researches on plant pigments, especially chlorophyll.

1915 Robert Thorburn Ayton Innes (1861–1933), Scottish astronomer, discovers a faint star near Alpha Centauri that is a third companion to that binary (double) star. It is also the closest star to Earth (excluding our own sun), and is therefore called Proxima Centauri.

1915 Walter Sydney Adams (1876–1956), American astronomer, studies the spectrum of the companion star of Sirius and finds it to be hotter than our own sun. Since Adams knows its mass to be about that of Earth, he realizes it must be super-dense. This comes to be known as a white dwarf.

1915 Albert Einstein (1879–1955), German-Swiss-American physicist, completes four years of work on his theory of gravitation or what becomes known as the general theory of relativity.

1916 Arnold Johannes Wilhelm Sommerfeld (1868–1951), German physicist, modifies the Bohr model of the atom by suggesting that the electron paths are elliptical. By doing this he applies Einstein's relativity theory to the atom.

1916 Peter Jospeh Wilhelm Debye (1884–1966), Dutch-American physical chemist, demonstrates that x ray analysis can be used for powdered as well as intact crystals, thus inventing powder crystallography.

1916 Edward Emerson Barnard (1857–1923), American astronomer, discovers the fastest-moving known star. Named "Barnard's Runaway Star," it is one of the closest to our solar system, thus accounting for its great speed.

1916 First establishment of timing of ovulation in humans is accomplished.

1916 First journal devoted purely to genetics in the United States is founded, *Genetics.*

1916 Gilbert Newton Lewis (1875–1946), American chemist, publishes *The Atom and the Molecule*, in which he introduces his "even number" rule of electrons.

1916 Gilbert Newton Lewis (1875–1946), American chemist, suggests the phenomenon of shared electrons in nonionic chemical compounds. He states that a bond between two elements can be formed by the sharing of an electron and that the final result is that all atoms achieve the stable electron configuration of the inert gas atom.

1916 Giuliano Vanghetti (1861–1940), Italian surgeon, advances plastic surgery with the introduction of cineplastic treatment of amputated stumps, which makes use of the remaining muscles to better work the prosthesis. The mutilations inflicted on soldiers during World War I provide surgeons ample challenges and opportunities to advance their craft.

1916 Henry Drysdale Dakin (1880–1952), English chemist, introduces chloramine as a sterilizing agent for purifying drinking water.

1916 Jay McLean (1890–1957), American physiologist, first isolates the anticoagulant called heparin.

1916 Karl Schwarzschild (1873–1916), German astronomer, is the first to offer a solution to Einstein's equations for general relativity and the first to calculate the gravitational phenomena in the environs of a star whose entire mass is concentrated in one point. This comes to be known as a "Schwarzschild singularity" or a black hole.

1916 Kotaro Honda (1870–1954), Japanese metallurgist, discovers that the addition of cobalt to tungsten steel produces an alloy capable of forming an extremely powerful magnet.

1916 Theodore Charles Lyster (1875–1933), American surgeon and founder of aviation medicine in the United States, establishes physical standards for pilots based on empirical grounds.

1916 Thomas Crowder Chamberlin (1843–1928), American geologist, offers his planetesimal hypothesis in *The Origin of the Earth.* This argument states that a star once passed near the sun, pulling matter from it that later condensed and formed the planets.

1916 Albert Einstein (1879–1955), German-Swiss-American physicist, publishes a paper stating his general theory of relativity. In this large theory about the universe as a whole, he states that light will be deflected by a gravitational field significantly more than it would in Newtonian theory.

1917 Charles Glover Barkla (1877–1944), English physicist, wins the Nobel Prize for physics for his discovery of the characteristic Roentgen radiation of the elements.

1917 A 100 inch (2.5 meter) reflecting telescope is placed on Mount Wilson, near Pasadena, California. It is paid for by American hardware tycoon John Daggett Hooker (1838–1911) and is the largest telescope in the world for a generation.

1917 Adolf Windaus (1876–1959), German organic chemist, extracts cholestrin (later known as vitamin D) from cod liver oil and formulates it.

1917 Calvin Blackman Bridges (1889–1938), American geneticist, discovers the first chromosome deficiency.

1917 D'Arcy Wentworth Thompson (1860–1948), Scottish zoologist, publishes his *On Growth and Form*, which views the evolution of one species into another as a process of major transformations involving the whole organism, rather than successive, minor changes in the body parts.

1917 James Hopwood Jeans (1877–1946), English mathematician and astronomer, uses mathematics to study the breakup of rapidly spinning bodies under the stress of centrifugal force and invalidates Laplace's nebular hypothesis (which stated that the planets and sun condensed from a single gaseous cloud). He then proposes Chamberlin's catastrophic theory (1900), which says that planetary material was drawn away from the sun after a near-collision.

1917 Otto Hahn (1879–1968), German physical chemist, and Lise Meitner (1878–1968), Austrian-Swedish physicist, discover the new element protoactinium (atomic number 91). It is independently discovered by Polish chemist Kasimir Fajans (1887–1975) as well as by the English team of Frederick Soddy (1877–1956), John Cranston, and Alexander Fleck (1889–1968).

1917 Walter Edward Dandy (1886–1946), American neurosurgeon, first introduces ventriculography with air. This diagnostic procedure is an x ray process that images the brain's cerebral ventricles by injecting air into them, which displaces their cerebrospinal fluid.

1918 Max Karl Ernst Ludwig Planck (1858–1947), German physicist, wins the Nobel Prize for physics for his discovery of energy quanta.

1918 Annie Jump Cannon (1863–1941), American astronomer, develops a classification system of stellar spectra that forms the basis for the *Henry Draper Catalogue*. The first volume of this nine-volume work is published this year and it is based on her spectral classification.

1918 First blood and serum banks are established in Europe during World War I.

1918 Fritz Haber (1868–1934), German chemist, is awarded the Nobel Prize for chemistry for the synthesis of ammonia from its elements.

1918 Hans Spemann (1869–1941), German embryologist, invents grafting techniques.

1918 Harlow Shapley (1885–1972), American astronomer, uses the new 100-inch (2.5-m) reflecting telescope on Mount Wilson and determines the distances of the globular clusters. These are closely packed, spherically-shaped groups of up to 100,000 stars. With this, he is able to make a three-dimensional model of them, which allows him to offer, for the first time, a picture of our galaxy that is close to its actual immense size. His model removes the sun from its supposed position as the center of the galaxy, but more importantly, it marks the real beginning of galactic astronomy.

1918 Jaroslav Heyrovsk (1890–1967), Czech physical chemist, invents "polarography," an extremely delicate analytical system for determining the concentration of ions in a solution of unknown composition.

1918 The Army School of Nursing is established to relieve the severe shortage of nurses. It becomes the major source of career Army nurses until it is closed in 1931 as an economy measure.

1918 Waldemar Lindgren (1860–1939), Swedish geologist, introduces the law of equal volume replacement to geology.

1918 Calvin B. Bridges (1889–1938) discovers chromosomal duplications in *Drosophila* (fruit flies).

1918 Thomas H. Morgan (1866–1945) demonstrates further evidence of the correlation between the number of linkage groups in *Drosophila melanogaster* and the haploid number of chromosomes in that species.

1918 The influenza epidemic of 1918–1919 begins to rage across most of the world. The incredibly high mortality rates are attributed to the rapidity with which it develops into pneumonia and secondary complications. Influenza victims die very rapidly. The worldwide death toll has been set at 22 million, a figure most regard as low. In the United States, influenza mortality is in excess of 550,000.

1919 Ernest Rutherford (1871–1937), British physicist, accomplishes the first form of artificial fission. He succeeds, through atomic bombardment with subatomic particles, in altering an atomic nuclei and transforming one element into another. This can be described as the first man-made nuclear reaction.

1919 Heinrich Barkhausen (1881–1956), German physicist, discovers that a slow, smooth increase of a magnetic field applied to a piece of ferromagnetic material like iron causes it to become magnetized in discontinuous jumps accompanied by loud clicks rather than quietly and continuously. This comes to be called the Barkhausen effect.

1919 Johannes Stark (1874–1957), German physicist, wins the Nobel Prize for physics

for his discovery of the Doppler effect in canal rays and the splitting of spectral lines in electric fields.

1919 Arthur Stanley Eddington (1882–1944), English astronomer and physicist, leads an expedition to photograph stars during a solar eclipse. Comparison with pre-eclipse photos shows starlight to be deflected. This confirms the bending of light rays passing through a strong gravitational field as predicted by Albert Einstein's general theory of relativity.

1919 Ernest Sachs (1879–1958), American neurosurgeon, receives the professorship of neurosurgery at the Washington University School of Medicine (St. Louis, Missouri). This is the first such professorship awarded anywhere in the world.

1919 Ernest William Brown (1866–1938), English-American astronomer, publishes improved tables of the moon's motion that become the standard.

1919 Francis Gilman Blake (1887–1952) and James Dowling Trask (1890–1942), both American physicians, first demonstrate that measles is caused by a virus.

1919 Francis William Aston (1877–1945), English chemist and physicist, develops the mass spectrometer and proves the existence of isotopy or isotopes (atoms of the same element with differing atomic weights).

1919 International Astronomical Union is founded in Brussels, Belgium, to promote the study of astronomy and facilitate cooperation among astronomers.

1919 Joseph Larmor (1857–1942), English physicist, is the first to explain the splitting of spectrum lines by a magnetic field. He also explains Earth's and the sun's magnetic fields.

1919 Jules-Jean-Baptiste-Vincent Bordet (1870–1961), Belgian bacteriologist, is awarded the Nobel Prize for physiology or medicine for his discoveries relating to immunity.

1919 Kurt Huldschinsky, German physician, first demonstrates the curative effect of sunlight (ultraviolet rays) in the treatment of rickets.

1919 Mercurochrome is first introduced by Hugh Hampton Young (1870–1945), American urologist, and colleagues E.C. White and E.O. Schwarz. This red organic mercury-containing dye is used as an antiseptic and germicide and becomes very popular for treating minor cuts.

1919 James Brown uses blood agar to study the destruction of blood cells by the bacterium *Streptococcus.* He observes three reactions that he designates alpha, beta, and gamma.

1919 The Health Organization of the League of Nations is established for the prevention and control of disease around the world.

1920 Charles Edouard Guillaume (1861–1938), Swiss-French physicist, wins the Nobel Prize for physics for his discovery of anomalies in nickel steel alloys.

1920 Francis William Aston (1877–1945), English chemist and physicist, uses his mass spectrograph to formulate the whole-number rule. This states that with the mass of oxygen defined as exactly sixteen, all other isotopes have masses that are very nearly whole numbers. This notion becomes fundamental to the development of nuclear theory.

1920 William Draper Harkins (1873–1951), American chemist, explores nuclear chemistry and predicts both the existence of the neutron and of heavy hydrogen.

1920 Albert Abraham Michelson (1852–1931), German-American physicist, makes the first measurement of the diameter of a star other than the sun. Using a stellar interferometer of his own design, he determines that Alpha Orionis (Betelgeuse) has a diameter of 260 million miles (418 million km).

1920 Edgar Douglas Adrian (1889–1977), English physiologist, isolates single nerve fibers and measures their impulses.

c. 1920 George Hoyt Whipple (1878–1976), American pathologist, discovers the active principle in liver that affects the formation of blood. In 1926, Whipple's results lead the American physicians George Richards Minot (1885–1950) and William Parry Murphy (1892–1987) to treat pernicious anemia successfully with liver.

1920 Hearing aids that are electrically-amplified bone conductor types are first introduced in England by S.G. Brown.

1920 Heber Doust Curtis (1872–1942) and Harlow Shapley (1885– 1972), both American astronomers, engage in the "Great Debate" concerning the size of our galaxy. It is eventually resolved by Hubble's work in 1924.

1920 Hermann Walther Nernst (1864–1941), German physical chemist, is awarded the Nobel Prize for chemistry for his work in thermochemistry.

1920 International Union Against Tuberculosis is founded at Geneva, Switzerland.

1920 Louis Rehn (1849–1930), German surgeon, performs the first successful pericardiectomy. This heart operation on the thickened pericardium has since saved many lives.

1920 Otto Loewi (1873–1961), German-American physiologist, demonstrates the importance of chemical mediators in transmitting or triggering nerve impulses.

1920 Schack August Steenberg Krogh (1874–1949), Danish physiologist, is awarded the Nobel Prize for physiology or medicine for discovering the causes of the constriction and expansion of the small blood vessels, called capillaries, that regulate the flow of blood throughout the body.

1921 Albert Einstein (1879–1955), German-Swiss-American physicist, wins the Nobel Prize for physics for his discovery of the law of the photoelectric effect.

1921 Charles Foix (1882–1927), French neurologist, first locates the cause of paralysis agitans (what we now know as Parkinson's disease) in the midbrain's substantia nigra.

1921 American Birth Control League is founded.

1921 Boris Petrovich Uvarov studies migrating swarms of grasshoppers and is the first to realize that overcrowding of larvae in a restricted area can cause physiological and even morphological alterations that can modify behavior.

1921 Frederick Grant Banting (1891–1941), Canadian physician, Charles Best (1899–1978), Canadian physiologist, John J.R. Macleod (1876–1935), Scottish-American physiologist, and Canadian James Collip (1892–1965) discover insulin. They develop a method of extracting insulin from the human pancreas and then injecting it into the blood of diabetics to lower their blood sugar.

1921 Frederick Soddy (1877–1956), English chemist, is awarded the Nobel Prize for chemistry for his contributions to our knowledge of the chemistry of radioactive substances and his investigations into the origin and nature of isotopes.

1921 George Tully Vaughan, American physician, performs the first successful ligation of the abdominal aorta.

1921 Jules Gonin (1870–1935), Swiss ophthalmologist, performs an operation for retinal detachment (and possibly pioneers microsurgery).

1921 Meghnad N. Saha (1893–1956), Indian astrophysicist, demonstrates that the spectrum of a light source like a star depends as much on its temperature as on its chemical composition. He is one of the first to apply the new physics to the study of stellar spectra.

1921 Otto Loewi (1873–1961), German-American physiologist, discovers that acetylcholine functions as a neurotransmitter. It is the first such brain chemical to be so identified.

1921 Thomas Hunt Morgan (1866–1945), American geneticist, offers the first estimate for the size of genes.

1921 Thomas Midgley, Jr. (1889–1944), American chemist, discovers the anti-knock properties of tetraethyl lead and develops the mixture of it and ethylene dibromide and dichloride that is soon adopted throughout the world to increase the octane rating of gasoline.

1921 Victor Moritz Goldschmidt (1888–1947), Swiss-Norwegian geochemist, publishes *Die Injektionmetamorphose im Stavanger-Gebiete*, which studies the structures created by the penetration of magma or other rock into existing deposits.

1921 Lilian Vaughn Morgan (1870–1952) discovers attached-X chromosomes in *Drosophila* (fruit flies).

1922 Niels Henrik David Bohr (1885–1962), Danish physicist, wins the Nobel Prize for

physics for his services in the investigation of the structure of atoms and of the radiation emanating from them.

1922 Albert-Léon-Charles Calmette (1863–1933), French bacteriologist, and Camille Guérin discover a preventive tuberculosis vaccine consisting of living cultures.

1922 Aleksandr Evgenevich Fersman (1883–1945), Russian geochemist and mineralogist, publishes his *Geokhimia Rossii*, which focuses for the first time on regional geochemistry and establishes him as one of the founders of geochemistry.

1922 Alexander Friedmann (1888–1925), Russian mathematician, publishes the first evolutionary model of the universe that contains an expansion element. He is also one of the first to postulate a "big bang" model for the evolution of the universe.

1922 Archibald Vivian Hill (1886–1977), English physiologist, is awarded the Nobel Prize for physiology or medicine for his discovery relating to the production of heat in the muscle. Otto Fritz Meyerhoff (1884–1951), German-American biochemist, is also awarded the Nobel Prize for physiology or medicine for his discovery of the fixed relationship between the consumption of oxygen and the metabolism of lactic acid in the muscle.

1922 Ernest Verner McCollum (1879–1967), American biochemist, discovers and names vitamin D as an antiricket substance found in cod liver oil.

1922 Fernando E. Rodriguez, working at the U.S. Army Dental School, demonstrates the cycle of tooth decay and the role of bacteria and lays the foundation for modern preventive dentistry.

1922 Francis William Aston (1877–1945), English chemist and physicist, is awarded the Nobel Prize for chemistry for his discovery, by means of his mass spectrograph, of isotopes in a large number of nonradioactive elements and for his enumeration of the whole-number rule.

1922 Gastroscopy (a method of viewing the interior of the stomach) is introduced for clinical use.

1922 Henry Stephens Washington (1867–1934), American geochemist and petrologist, produces the first reliable data on the concentration of elements within Earth.

1922 Herbert McLean Evans (1882–1971), American anatomist, embryologist, and physician, and colleagues discover vitamin E.

1922 Herman Zanstra (1894–1972), Dutch astrophysicist, develops the theory of nebular emission lines and advances knowledge of how this light is actually transmitted.

1922 Insulin is administered for the first time to a patient with diabetes mellitus.

1922 John Stanley Plaskett (1865–1941), Canadian astronomer, uses a 72-inch (1.8-m) reflecting telescope of his own design and discovers what comes to be known as Plaskett's twins. Previously thought to be a single star, this is really a binary star of unusually large size.

1922 William Weber Coblentz (1873–1962), American physicist, invents a thermocouple (a loop made of two different metals) that enables astronomers to calculate the temperatures of planets. Using a very sensitive thermocouple in a vacuum placed at the focus of a telescope, Coblentz obtains the surface temperature of the planet Mercury.

1923 Arthur Holly Compton (1892–1962), American physicist, discovers what comes to be called the Compton effect. While accurately measuring the wavelengths of scattered x rays, he discovers that some of the rays lengthen their wavelength in scattering. He accounts for this by stating that a "photon" of light strikes an electron, which recoils and subtracts some energy from the photon, therefore increasing its length. It is Compton who coins the term photon to describe light as a particle.

c. 1923 Franz Eugen Francis Simon (1893–1956), German-British physicist, begins his lifelong work in low temperature physics. He goes on to develop small-scale low-temperature apparatuses of ingenious design and eventually provides solid backing for Nernst's third law of thermodynamics.

1923 Louis Victor de Broglie (1892–1987), French physicist, introduces the particle-

wave hypothesis, stating that an electron or any other subatomic particle can behave either as a particle or as a wave. This idea is confirmed in 1927.

1923 Robert Andrews Millikan (1868–1953), American physicist, wins the Nobel Prize for physics for his work on the elementary charge of electricity and on the photoelectric effect.

1923 Adolph Melanchton Hanson, American surgeon, obtains the first really effective parathyroid gland extract from cattle.

1923 American surgeons Evarts Ambrose Graham (1883–1957) and Warren Henry Cole introduce the first successful cholecystography. They inject an opaque dye and are able to x ray the gallbladder.

1923 Carlos Williamson describes rejection phenomenon.

1923 Edward Arthur Milne (1896–1950), English mathematician and astrophysicist, demonstrates that the sun can eject atoms at speeds of up to 994 miles per second (1,600 km/s). This marks the beginning of the notion of the "solar wind."

1923 Ernest Henry Starling (1866–1927), English physiologist, publishes his *Wisdom of the Body*, in which he emphasizes the importance of the endocrine system in regulating the homeostasis of an organism.

1923 Felix Andries Vening Meinesz (1887–1966), Dutch geophysicist, develops a method of measuring gravity in ocean basins by means of a pendulum device carried in a submarine.

1923 Frederick Grant Banting (1891–1941), Canadian physiologist, and John James Richard Macleod (1876–1935), Canadian physiologist, are awarded the Nobel Prize for physiology or medicine for their discovery of insulin.

1923 Fritz Pregl (1869–1930), Austrian chemist, is awarded the Nobel Prize for chemistry for his invention of the method of microanalysis of organic substances.

1923 Gaston Ramon (1886–1963), French bacteriologist, discovers the anti-diphtheria and anti-tetanus vaccines.

1923 Georg von Hevesy (1885–1966), Hungarian chemist, first uses radioactive tracers to follow the path of a substance in an organism.

1923 George Frederick Dick (1881–1967), American physician and bacteriologist, and Gladys Rowena Dick (1881–1963) discover the hemolytic streptococcus of scarlet fever and develop a skin test to determine susceptibility.

1923 Gilbert Newton Lewis (1875–1946), American chemist, publishes his *Thermodynamics and the Free Energy of Chemical Substances.* It introduces and explains the thermodynamics of pioneer American physicist Josiah Willard Gibbs (1839–1903) to students and becomes the classic book in its field.

1923 Georg von Hevesy (1885–1966), Hungarian-Danish-Swedish chemist, and colleagues discover the new element hafnium.

1923 Hans Spemann (1869–1941), German zoologist, introduces and perfects the technique of research transplants while studying embryonic development in frogs.

1923 Johannes Nicolaus Bronsted (1879–1947), Danish chemist, studies hydrogen ions and their role in acid-base relationships and clarifies what becomes the modern notion of acids and bases.

1923 Louis Victor de Broglie (1892–1987), French physicist, demonstrates that with any elementary moving particle there is an associated wave. This contributes to the new wave concept of the atom.

1923 Max Wertheimer (1880–1943), German psychologist, publishes *Untersuchungen zur Lehre der Gestalt*, which first originates the concept of Gestalt psychology. This school of psychological thought attempts to examine the total, structured forms of mental experience.

1923 Robert Andrews Millikan (1868–1953), American physicist, establishes that the air absorbs cosmic radiation but is not the place it originates. Two years later, he conducts experiments at the bottom of an extremely deep lake and disproves the theory that cosmic radiation is only extremely high-energy electromagnetic waves.

1923 Theodor H.E. Svedberg (1884–1971), Swedish chemist, introduces the first ultra-

centrifuge. This device whirls so fast that it can remove particles from colloidal suspension, because it can produce an effect equal to hundreds of thousands of times the force of normal gravity. The device makes it possible to obtain proteins in the pure state and to evaluate their molecular weight.

1923 Victor Moritz Goldschmidt (1888–1947), Swiss-Norwegian geochemist, publishes the first of an eight-volume study, *Geochemische Verteilungsgesetze der Elemente*, that forms the foundation of inorganic chemistry. He is the first to be able to predict the formation of specific minerals from the connection between specific element combinations and certain geological conditions.

1923 A.E. Boycott and Diver describe a classic example of "delayed Mendelian inheritance." The direction of the coiling of the shell in the snail *Limnea peregra* is under genetic control, but the gene acts on the egg prior to fertilization. Thus, the direction of coiling is determined by the egg cytoplasm, which is controlled by the mother's genotype.

1924 Edward Victor Appleton (1892–1965), English physicist, discovers that radio waves are reflected by an ionized layer of the atmosphere. He studies this layer and measures distance to it by timing radio signals. It eventually becomes known as the Appleton layer.

1924 Hendrik Anthony Kramers (1894–1952), Dutch physicist, predicts the existence of an inelastic scattering of light that later comes to be called the Raman effect.

1924 Karl Manne Georg Siegbahn (1886–1978), Swedish physicist, develops improved techniques to produce x rays whose wavelengths can be accurately measured. His improvements in x-ray spectroscopy are such that he is able to produce an actual x-ray spectra for each element. He also is the first to refract x rays with a prism.

1924 Karl Manne Georg Siegbahn (1886–1978), Swedish physicist, wins the Nobel Prize for physics for his discoveries and research in the field of x-ray spectroscopy.

1924 Otto Stern (1888–1969), German-American physicist, studies molecular beams and establishes that atoms and molecules behave like tiny magnets when protons and electrons are charged.

1924 Satyendranath Bose (1894–1974), Indian physicist, publishes a paper in which he devises a new statistical method of dealing with Planck's quantum theory. It is adopted by Einstein who uses it to deduce that matter should exhibit wave properties.

1924 Albert-Léon Charles Calmette (1863–1933), French bacteriologist, invents the antituberculosis vaccine using attenuated live bacilli and vaccinates children.

1924 Arthur Stanley Eddington (1882–1944), English astronomer and physicist, shows that a star's brightness varies as the cube of its mass.

1924 Edwin Powell Hubble (1889–1953), American astronomer, founds the study of the universe beyond our own galaxy (based on his own findings that some of the nebulae are really separate galaxies of gas, dust, and stars). He then goes on to develop the first system for their classification (according to shape).

1924 Edwin Powell Hubble (1889–1953), American astronomer, is the first to locate stars in the Andromeda nebula, determining that some are Cepheid variables. His calculations of distance indicate that the Andromeda nebula is outside our own galaxy. He provides proof that other galaxies are truly independent systems rather than part of our own Milky Way.

c. 1924 Ernst Julius Opik (1893–1985), Estonian astronomer, works out the theory of the entry of high-speed bodies into the atmosphere. His work becomes fundamental to the theory of ablation or the peeling back of surfaces during vaporization. This work becomes vitally important to the U.S. manned space program during the 1960s, when it develops heat shields for reentry.

c. 1924 Eugene Floyd DuBois (1882–1959), American physiologist, establishes basal metabolism standards expressed in tabular form

on the basis of calories per square meter per hour.

1924 First petroleum deposit discovered by using the seismic refraction method is made at Orchard Dome, Texas.

1924 Harold Jeffreys (1891–1989), English astronomer, publishes *Earth: Its Origin, History, and Physical Constitution.* He is among the first to speak of Earth's age in terms of several billions of years instead of tens of millions.

1924 Kenneth Lord first uses the word "rayon" to describe synthetic cellulose fibers.

1924 Ko Kuei Chen, Chinese-American pharmacologist, and Carl Frederick Schmidt, American physician, first introduce ephedrine. Similar to epinephrine but less powerful, it has the advantage of being taken orally. This marks the introduction to Western medicine of a drug called "ma huang," which has been used in China for 5,000 years.

1924 Otto Heinrich Warburg (1883–1970), German biochemist, and E. Negelein first measure the efficiency of photosynthesis. The device they use is called a Warburg manometer.

1924 Richard Hesse (1868–1944) of Germany publishes his *Tiergeographie auf (tm)kologischer Grundlage*, which is considered the first real zoogeographic text that analyzes problems related to the environmental distribution of animals from a strictly ecological point of view.

1924 Wilhelm J. Schmidt of Germany develops the polarizing microscope.

1924 Willem Einthoven (1860–1927), Dutch physiologist, is awarded the Nobel Prize for physiology or medicine for his discovery of the mechanism of the electrocardiogram.

1924 Alfred H. Sturtevant (1891–1970) analyzes the Barr-eye phenomenon in *Drosophila* and discovers position effect.

1924 Albert Jan Kluyver publishes *Unity and Diversity in the Metabolism of Microorganisms.* He demonstrates that different microorganisms have common metabolic pathways of oxidation, fermentation, and synthesis of certain compounds. Kluyver also states that life on Earth depends on microbial activity.

1925 James Franck (1882–1964), German-American physicist, and Gustav Ludwig Hertz (1887–1975), German physicist, win the Nobel Prize for physics for their discovery of the laws governing the impact of an electron upon an atom.

1925 Robert Andrews Millikan (1868–1953), American physicist, names the radiation coming from outer space "cosmic rays."

1925 Werner Karl Heisenberg (1901–1976), German physicist, develops a new system of mathematics called matrix mechanics; it employs columns of numbers that describe all possible transitions within an atom. The solutions to the matrix correspond to the wavelengths of the hydrogen spectral lines.

1925 American Army Colonel Calvin H. Goddard (1891–1955) begins his pioneering work in forensic ballistics. Over several decades he develops the first accurate method for comparing a fired bullet with one experimentally fired from a suspected weapon. He also studies rifling characteristics and the effects of projectiles on the human body.

1925 David Keilin (1887–1963), Russian-English biochemist, discovers the cytochrome, a respiratory enzyme that acts as a catalyst for the combination of oxygen with hydrogen within the cells.

1925 Edward Bright Vedder (1878–1952), American physician, publishes *The Medical Aspects of Chemical Warfare.* It is the first American text to consider the modern medical problems of gas warfare.

1925 First sympathectomy as a remedy for hypertension is conducted by Leonard George Rowntree, American physician, and Alfred Washington Adson (1887–1951), American surgeon. This extensive operation, which severs the pathways of the sympathetic nervous system, offered only temporary results and was eventually replaced by drug therapy.

1925 Florence Rena Sabin (1871–1953), American anatomist and biologist, becomes

the first woman member of the National Academy of Sciences.

1925 Johannes Hans Berger (1873–1941), German neurologist, records the first human electroencephalogram (EEG). He demonstrates that the electrical activity of the human brain can be recorded through the scalp.

1925 John Masson Gulland (1898–1947), Scottish chemist, and R. Robinson propose the definitive structure of morphine, solving a problem that had perplexed chemists for nearly four decades.

1925 Karl Terzaghi (1883–1963), Czech-American engineer, publishes his *Erdbaumechanik auf Bodenphysikalischer Grundlage,* which founds the branch of civil engineering known as soil mechanics. This is the study of the properties of soil under stresses and under the action of flowing water.

1925 Richard Adolf Zsigmondy (1865–1929), Austrian-German chemist, is awarded the Nobel Prize for chemistry for his demonstration of the heterogeneous nature of colloid solutions and for the methods he used, which have since become fundamental in modern colloid chemistry.

1925 U.S. Army doctors Joseph F. Siler, Milton W. Hall, and Arthur P. Hitchens demonstrate the transmission of the dengue virus by the *Aedes aegypti* mosquito.

1925 W. Vogt devises a method of marking cells with stains and is able to follow various cells in the course of their normal development. He discovers that cells perform complex, programmed migrations and this opens the way to a new branch of embryology, developmental kinematics.

1925 Walter Karl Friedrich Noddack (1893–1960) and Ida Eva Tacke (later Noddack; 1896–1978), both German chemists, discover the new element rhenium (atomic number 75). They marry in 1926 and continue to work together.

1925 Wolfgang Pauli (1900–1958), Austrian-American physicist, announces his discovery of the exclusion principle, which develops into one of the most powerful basic descriptive tools in physics. It states that two electrons with the same quantum numbers cannot occupy the same atom. (No two electrons in a given atom can have all four quantum numbers the same.) This principle serves to explain the chemical properties of the elements.

1925 Patrick Maynard Stuart Blackett (1897–1974), English physicist, takes the first photographs of a nuclear reaction in progress. To achieve this he uses a Wilson cloud chamber and takes over 20,000 photographs of more than 400,000 alpha particle tracks and observes 8 actual collisions of an alpha particle and a nitrogen molecule.

1925 George Eugene Uhlenbeck (1900–1988) and Samuel Abraham Goudsmit (1902–1978), both Dutch-American physicists, consider Pauli's exclusion principle from an experimental standpoint and state that it could also be explained if the electron is considered as spinning on its own axis and able to spin clockwise and counterclockwise.

1926 Jean Baptiste Perrin (1870–1942), French physicist, wins the Nobel Prize for physics for his work on the discontinuous structure of matter, especially for his discovery of sedimentation equilibrium.

1926 John Desmond Bernal (1901–1971), English physicist, advances x-ray crystallography by developing the Bernal chart, with which he can deduce crystal structure by analyzing photographs of x-ray diffraction patterns.

1926 Arthur Stanley Eddington (1882–1944), English astronomer and physicist, publishes *The Internal Constitution of the Stars,* which is the first major work on stellar structure.

1926 Barend C.P. Jansen and Willem F. Donath, both Dutch biochemists, first isolate thiamin.

1926 Bertil Lindblad (1895–1965), Swedish astronomer, studies the rotation of the galaxy in light of the motion of stars. He decides correctly that its central core rotates as a unit, while the outskirts of the galaxy revolve slower as the distances increase.

1926 Charles Robert Harington (1897–1972), English biochemist, determines the chemical structure of the thyroid hormone thyroxine.

1926 Dutch biochemists Barend C.P. Jansen and Willem F. Donath first isolate vitamin B_1.

1926 Erwin Schrödinger (1887–1961), Austrian physicist, works out the fundamental mathematical equation of wave mechanics, which places Planck's quantum theory on a firm mathematical basis.

1926 George Richards Minot (1885–1950) and William Parry Murphy, both American physicians, first introduce their raw liver diet in the treatment of pernicious anemia.

1926 Hermann Staudinger (1881–1965), German chemist, begins work on the nature of polymers (large molecules) and discovers that all of the various plastics being produced are similar polymers with simple units arranged in a straight line.

1926 James Batcheller Sumner (1887–1955), American biochemist, conducts the first crystallization of an enzyme. In extracting urease (urea) from the jack bean, he realizes that the crystals he isolates are both enzymes and proteins.

1926 Johannes Andreas Grib Fibiger (1867–1928), Danish bacteriologist, is awarded the Nobel Prize for physiology or medicine for his discovery of the Spiropter carcinoma. He is the first scientist to induce cancer in laboratory animals.

1926 Joseph Goldberger (1874–1929), American pathologist, and colleagues discover the cause and cure of the disease pellagra. This disease leads to a severe skin condition, diarrhea, and eventually a coma and death. He discovers that it is caused by a diet totally deficient in niacin (vitamin B_3) and protein.

1926 Louis Hopewell Bauer (1888–1964) of the U.S. Army School of Aviation publishes *Aviation Medicine*, the first American textbook concerned with the prevention and treatment of an aviator's medical problems.

1926 Otto Heinrich Warburg (1883–1970), German biochemist, is the first to determine that cancer cells derive energy from lactic acid fermentation and can therefore be damaged by radiation.

1926 Peter Muhlens (1874–1943) of Germany and colleagues introduce the first synthetic anti-malarial drug called Plasmoquin.

1926 Rudolf Magnus (1873–1927), German physiologist, discovers how the inner ear regulates balance.

1926 Theodor H.E. Svedberg (1884–1971), Swedish chemist, is awarded the Nobel Prize for chemistry for his work on disperse systems.

1926 J.B.S. Haldane suggests that the genes known to control certain coat colors in various rodents and carnivores may be evolutionarily homologous.

1926 Thomas C. Vanterpool publishes a paper that clarifies the problem of "mixed infections" of plant viruses. His study of the condition known as "streak" or "winter blight" of tomatoes shows that it was the result of simultaneous infection of tomato plants by tomato mosaic virus and a potato mosaic virus.

1926 Bernard O. Dodge begins genetic studies on *Neurospora*.

1926 Erwin Schrodinger (1887–1961), Austrian physicist, publishes a paper in which he mathematically develops wave mechanics and offers what comes to be known as the Schrodinger wave equation. This replaces the electron in the Bohr model of the atom with wave trains. This explanation becomes so satisfactory that it finally places Planck's quantum theory on a firm mathematical basis.

1926 Enrico Fermi (1901–1954), Italian-American physicist, introduces Fermi-Dirac statistical mechanics. This theory explains the behavior of "clouds" of electrons in a substance and also shows that gas particles obey Pauli's exclusion principle.

1926 Llewellyn Hilleth Thomas (1903–1992), English physicist, studies electron distribution in atoms and molecules and completes the development of the concept of electron spin.

1926 Max Born (1882–1970), German-British physicist, publishes his first paper on the

probability interpretation of quantum mechanics. In working out the mathematical basis of quantum mechanics, he gives electron waves a probabilistic interpretation as to their behavior.

1926 Gilbert Newton Lewis (1875–1946), American chemist, first introduces the term "photon" to describe the minute, discrete energy packet of electromagnetic radiation that is essential to quantum theory.

1926 Eugene Paul Wigner, Hungarian-American physicist, develops the principles involved in applying group theory to quantum mechanics and evolves the concept of the symmetry in space and time that marks the behavior of subatomic particles.

1927 Arthur Holly Compton (1892–1962), American physicist, and Charles Thomson Rees Wilson (1869–1959), Scottish physicist, share the Nobel Prize for physics. Comptons wins for his discovery of the effect named after him, and Wilson wins for his method of making the paths of electrically charged particles visible by condensation of vapor.

1927 Clinton Joseph Davisson (1881–1958), American physicist, has a laboratory accident that eventually leads him to discover that electrons or subatomic particles behave like waves. This confirms Louis Victor de Broglie's 1923 hypothesis.

1927 Fritz Wolfgang London (1900–1954), German-American physicist, and Walter Heinrich Heitler (1904–1981), German physicist, offer a quantum treatment of the hydrogen molecule. Their work is considered a major contribution to the understanding of chemical valence.

1927 George Paget Thomson (1892–1975), English physicist, discovers independently of Clinton Joseph Davisson or Max Theodor Felix von Laue the wave nature of electrons. This also confirms Louis Victor de Broglie's 1923 hypothesis.

1927 Paul Adrien Maurice Dirac (1902–1984), English physicist, develops equations that unite quantum mechanics and relativity theory.

1927 Werner Karl Heisenberg (1901–1976), German physicist, postulates his uncertainty principle, also known as the principle of indeterminacy. This states that it is impossible to determine accurately and simultaneously two variables of an electron (such as position and momentum). More generally, it states that when working at the level of atom-sized particles, the very act of measuring such particles affects significantly the results obtained. Philosophically, this is a troubling notion, for it calls into question much of our traditional belief in straight-forward cause and effect.

c. 1927 Willem Hendrik Keesom (1876–1956), Dutch physicist, is the first to solidify helium; he applies external pressure in combination with temperatures below 3° Kelvin. He also describes the unusual properties of the form of liquid helium called helium II. Its heat capacity changes abruptly, and all internal friction disappears.

1927 Albert Szent-Gyorgyi (1893–1986), Hungarian-American physicist, discovers ascorbic acid or vitamin C while studying oxidation in plants.

1927 Fritz Wolfgang London (1900–1954), German-American physicist, works out a quantum mechanical treatment of the hydrogen molecule, which provides the theoretical basis for the study of molecules in terms of the new (quantum) physics.

1927 Georges Henri Lemaître (1894–1966), Belgian astronomer and Roman Catholic priest, first formulates the modern big-bang theory of the origin of the universe. He holds that in a backward extrapolation of time, the galaxies can be viewed as initially existing all crushed together in a kind of "superatom" or "cosmic egg." This "superatom" is supposed to have contained all the matter in the universe—which then exploded.

1927 Heinrich Otto Wierland (1877–1957), German chemist, is awarded the Nobel Prize for chemistry for his investigations of the constitution of the bile acids and related substances.

1927 Henry Norris Russell (1877–1957), American astronomer, publishes a textbook in astronomy that for the first time shifts that subject's emphasis away from the solar system and toward the stars and astrophysics.

1927 Hermann Joseph Muller (1890–1967), American biologist, induces or causes the first artificial mutations in the *Drosophila* fruit fly by using x rays. His work shows that mutations are the result of some type of chemical change. It also alerts him to the danger of excessive x rays.

1927 Jan Hendrik Oort, Dutch astronomer, demonstrates that our galaxy is rotating. It does not rotate as a single unit however, for the stars near the center of the galaxy move faster while those farther out move slower.

1927 Julius Wagner-Jauregg (1857–1940), Austrian psychiatrist, is awarded the Nobel Prize for physiology or medicine for his discovery of the first successful therapy for syphilitic paresis of the insane by infecting patients with malaria.

1927 Lemuel Clyde McGee, American biochemist, obtains an active extract of the male sex hormone from bull testicles.

1927 Ruth Tunnicliff (1876–1946), American scientist, first introduces a serum to be used against measles.

1927 Selmar Aschheim and Bernhardt Zondek, both German physicians, devise a pregnancy test in which the subject's urine is injected subcutaneously in immature female mice. A positive reaction is marked by congestion and hemorrhages of the ovaries in the mice.

1927 Seth Barnes Nicholson (1891–1963), American astronomer, discovers that the surface of the moon drops nearly 392° F (200° C) during an eclipse by Earth's shadow. He interprets this large, quick drop as indicating that any heat in its core rises very slowly to the surface. He goes on to measure the maximum surface temperature of Mercury and to discover four more satellites of Jupiter.

1927 Lewis J. Stadler produces artificial mutations in barley and maize and demonstrates that the dose-frequency response is linear.

1927 Thomas Rivers publishes a paper that differentiates bacteria from viruses, establishing virology as a field of study that is distinct from bacteriology.

1927 Niels Henrik David Bohr (1885–1962), Danish physicist, states his principle of complementarity, saying that a phenomenon can be considered in each of two mutually exclusive ways, with each way staying valid in its own terms. He applies it specifically to the simultaneous wave and particle behavior of an electron, but it comes to be used by other disciplines besides atomic physics.

1928 Chandrasekhara Venkata Raman (1888–1970), Indian physicist, discovers what comes to be known as the Raman effect. While investigating light scattering, he finds that a change in the wavelength of light occurs when a beam of light is deflected by molecules. With Raman scattering, it is possible to determine what the molecules are, since the exact wavelengths produced depend on the nature of the molecules doing the scattering.

1928 George Gamow (1904–1968), Russian-American physicist, develops the quantum theory of radioactivity, which is the first theory to successfully explain the behavior of radioactive elements, some of which decay in seconds and others of which decay only after thousands of years.

1928 Hermann Weyl (1885–1955), German mathematician, publishes his *Gruppentheorie und Quatenmechanik*, in which he shows that most of the regularities of quantum phenomena on the atomic level can be most simply understood using group theory. His book helps mold modern quantum theory.

1928 Owen W. Richardson (1879–1959), English physicist, wins the Nobel Prize for physics for his work on the thermionic phenomenon, especially for the discovery of the law named after him.

1928 Adolf Windaus (1867–1959), German chemist, is awarded the Nobel Prize for chemistry for his research into the constitution of the sterols and their connection with vitamins.

1928 Albert Szent-Gyorgyi (1893–1986), Hungarian-American biochemist, first isolates and describes ascorbic acid. In 1931 he shows this to be identical to vitamin C.

1928 Alexander Fleming (1881–1955), Scottish bacteriologist, discovers penicillin. In his published report (published in 1929), Fleming observes that the mold *Penicillium notatum* inhibits the growth of some bacteria. This is the first of the antibacterials to be discovered, and it opens a new era of "wonder drugs."

1928 Charles J.H. Nicolle (1866–1936), French physician, is awarded the Nobel Prize for physiology or medicine for proving that typhus is transmitted to humans by the louse.

1928 Cyril Norman Hinshelwood (1897–1967), English physical chemist, studies chain-reaction mechanisms and shows that temperature determines whether a mixture of hydrogen and oxygen gases will explode or not. The Russian physical chemist, Nikolay Nikolaevich Semenov (1896–1986), independently discovers the same this year.

1928 Frederick Reece Griffith, Jr. (c.1879–1941), American physiologist, carries out the first experiment on the transformation of one type of pneumonia into another by putting the first in contact with some of the killed cells of the second. He shows that genetic information is transmitted chemically.

1928 George Nicholas Papanicolaou (1883–1962), Greek-American physician, invents the Pap test, a simple and painless procedure for the early detection of cervical and uterine cancer.

1928 James Hopwood Jeans (1877–1946), English mathematician and astronomer, is the first to propose that matter is continuously being created throughout the universe.

1928 N.K. Kolikov (1872–1970) introduces the concept of chromosome duplication, which later becomes the basis of molecular genetics.

1928 Oliver Kamm and his team first isolate vasopressin and oxytocin.

1928 Otto Paul Hermann Diels (1876–1954) and Kurt Alder (1902–1958), both German chemists, discover a technique of atomic combination that can be put to use in the formation of many synthetic compounds. It comes to be known as the Diels-Alder reaction.

c.1928 Wilder Graves Penfield (1891–1976), Canadian neurosurgeon, first uses microelectrodes to map parts of the human brain's cerebral cortex and locates their different functions.

1928 Eugene Paul Wigner, Hungarian-American physicist, works out the theory of conservation of parity, stating that an atom can fluctuate between two states but can only be in one at a time.

1929 John Douglas Cockcroft (1897–1967), English physicist, and Irish physicist Ernest Thomas Sinton Walton (1903–1995) devise the first particle accelerator, which produces proton beam energies up to 600,000 volts to bombard a variety of targets.

1929 Louis Victor de Broglie (1892–1987), French physicist, wins the Nobel Prize for physics for his discovery of the wave nature of electrons.

1929 Paul Adrien Maurice Dirac (1902–1984), English physicist, predicts the existence of "antielectrons" and antimatter.

1929 Walther Wilhelm Georg Franz Bothe (1891–1957), German physicist, invents "coincidence counting" by using two Geiger counters to detect the vertical direction of cosmic rays. This allows the measurement of extremely short time intervals, and he uses this technique to demonstrate that the laws of conservation and momentum are also valid for subatomic particles.

1929 Adolf Friedrich Johann Butenandt (1903–1994), German chemist, isolates estrone. He obtains this female sex hormone from the urine of pregnant women.

1929 Arthur Harden (1865–1940), English biochemist, and Hans Karl August Simon von Euler-Chelpin, German-Swedish chemist, are awarded the Nobel Prize for chemistry for their investigations on the fermentation of sugar and fermentative enzymes.

1929 Arthur Holmes (1890–1965), English geologist, uses the phenomenon of radioactive

transformation to estimate the age of Earth's rocks. He shows that Kelvin's ideas are incorrect, and he establishes Earth as about 4.6 billion years old.

1929 Casimir Funk (1884–1967), Polish biochemist, and Harrow obtain active male hormone from male urine.

1929 Christiaan Eijkman (1858–1930), Dutch physician, is awarded the Nobel Prize for physiology or medicine for his discovery that the disease beriberi is the result of a nutritional deficiency. He is also the first to experimentally establish a deficiency disease. Frederick Gowland Hopkins (1861–1947), English biochemist, is also awarded the Nobel Prize for physiology or medicine for his discovery of growth-stimulating vitamins.

1929 Clarence Norman Fenner (1870–1949), American geologist, and Charles Snowden Piggot, American chemist and geophysicist, use mass spectroscopy to make the first calculation of mineral age from lead isotopes.

1929 Edward Adelbert Doisy (1893–1986), American biochemist, isolates estrone from the urine of pregnant women

1929 Edwin Powell Hubble (1889–1953), American astronomer, first formulates the law, named after him, that states that galaxies recede from ours at speeds proportional to their distances. This marks the beginning of the theory of the expanding universe.

1929 George Gamow (1904–1968), Russian-American physicist, and colleagues hypothesize that thermonuclear processes produce the sun's heat and light.

1929 Howland, Campbell, Maltby, and Robinson achieve the first cure of hyperinsulinism by the removal of an islet cell tumor.

1929 Karl Lohmann discovers ATP (adenosine triphosphate), the molecule that acts as an energy converter in all living things.

1929 Motonari Matuyama (also Matsuyama; 1884–1958), Japanese geophysicist, publishes an article, "On the Directing of Magnetization of Basalt in Japan, Tyosen and Manchuria," in which he concludes that Earth's magnetic field reversed itself during the Miocene and the Quaternary Epochs.

1929 Otto Struve (1897–1963), Russian-American astronomer, shows that interstellar matter exists throughout the galaxy and is not only locally associated with individual star systems.

1929 P. Stricker and F. Grueter discover prolactin, a hormone secreted by the pituitary gland that begins and maintains the secretion of milk in female mammals.

1929 Philip Drinker (1893–1977), American industrial hygienist, invents the iron lung. This machine performs the function of the muscles that control breathing and is one of the first inventions that keeps people alive who are unable to breathe.

1929 The hormonal role of the corpus luteum is established by the American medical biologist George Washington Corner (1889–1991) and the American physician Willard Myron Allen (1904–1993). At the time, the luteal hormone was named progestin (and later progesterone). It is necessary for maintenance during early pregnancy.

1929 Werner Forssmann (1904–1979), German surgeon, invents the first practical system for cardiac catheterization. This insertion of a tube with dye into the heart makes for more accurate heart diagnoses without surgery. Forssmann first tests this on himself.

1929 William Francis Giauque (1895–1982), American chemist, discovers that oxygen is a mixture of three isotopes. This leads to a debate between chemists and physicists concerning an atomic weight standard; it is not resolved until 1961.

1929 Francis O. Holmes introduces a valuable technique, known as the "local lesion," as a means of measuring the concentration of tobacco mosaic virus. The method became extremely important in virus purification.

1929 Frank Macfarlane Burnet (1899–1985) and Margot McKie report critical insights into the phenomenon known as lysogeny (the inherited ability of bacteria to produce bacteriophage in the absence of infection). Burnet and McKie postulate the pres-

ence of a "lytic unit" as a normal hereditary component of lysogenic bacteria. The "lytic unit" is proposed to be capable of liberating bacteriophage when it is activated by certain conditions. This concept is confirmed in the 1950s.

1930 Chandrasekhara Venkata Raman (1888–1970), Indian physicist, wins the Nobel Prize for physics for his work on the scattering of light and for the discovery of the effect named after him.

1930 Arthur Compton (1892–1962), American physicist, confirms the latitude effect, which states that cosmic radiation reaches a minimum at zero degrees geomagnetic latitude and rises to a maximum at latitude fifty degrees, after which it remains constant. This is the first indication that Earth's magnetic field influences cosmic radiation.

1930 Bernard Ferdinand Lyot (1897–1952), French astronomer, invents the coronagraph. With it, astronomers no longer must wait for a total eclipse to study the coronal spectral lines of the sun, for his instrument focuses the light of the sun on an opaque disc and eliminates all scattered light from the atmosphere and from the lens itself.

1930 Burrhus Frederic Skinner (1904–1990), American psychologist, first describes operant conditioning. He makes advances in behaviorist research and on conditioned responses and goes on to invent teaching machines.

1930 Hans Fischer (1881–1945), German chemist, is awarded the Nobel Prize for chemistry for his researches into the constitution of haemin and chlorophyll and especially for his synthesis of haemin.

1930 John Howard Northrop (1891–1987), American biochemist, and Moses Kunitz (1887–1978) crystallize pepsin, the protein-splitting digestive enzyme in gastric secretions. This contributes to greater understanding of the chemical nature of enzymes.

1930 Karl Landsteiner (1868–1943), Austrian-American physician, is awarded the Nobel Prize for physiology or medicine for his discovery of the human blood groups.

1930 Nils Edlefsen (1893–1971) of the United States constructs the first cyclotron, under the direction of the American physicist Ernest Orlando Lawrence (1901–1958). This first instrument is a small machine that is used to produce directed beams of charged particles. Over the next few years, Lawrence continues to build larger instruments that eventually contribute to the discovery of new elements.

1930 Polystyrene is developed in Germany by the I.G. Farbenindustrie.

1930 Polyvinyl chloride is developed in the United States by the B.F. Goodrich Company.

1930 Robert Julius Trumpler (1886–1956), Swiss-American astronomer, shows that the light from the very distant globular clusters is dimmer than should be expected. He explains this correctly by saying that interstellar space is filled with superfine dust that dims light over vast distances. This is then used to show that Harlow Shapley's (1918) estimate of a galactic center that is 50,000 light-years away is too high, and that 30,000 is more accurate.

1930 Ronald Aylmer Fisher (1890–1962), English biologist, publishes *The Genetical Theory of Natural Selection*, which, together with Sewall Wright's (1889–1988) *Mendelian Populations* (1931), lays the mathematical foundations, and contributes to the advancement of, statistical methods of population genetics.

c.1930 The technique of using a needle to obtain samples of amniotic fluid (in which a fetus floats) from a mother's womb becomes available.

1930 Thomas Midgley, Jr. (1889–1944), American chemist, first prepares Freon (difluorodichloromethane) as a refrigerant gas. It comes to be used in all refrigerators, freezers, and air conditioning systems. Although neither poisonous nor inflammable, it is later believed to play a major role in the depletion of Earth's ozone layer.

1930 Max Theiler (1899–1972) demonstrates the advantages of using mice as experimental

animals for research on animal viruses. Theiler used mice in his studies of the yellow fever virus.

1930 Curt Stern (1902–1981), and, independently, Harriet B. Creighton (1909–2004) and Barbara McClintock (1902–1992), demonstrate cytological evidence of genetic crossing over between eukaryotic chromosomal strands.

1930 Clyde William Tombaugh (1906–1997), American astronomer, discovers Pluto, a new planet past Neptune. Using a photographic technique in which he compares two pictures of the same part of the sky taken on different days, he notices a slight shift in the position of one of them (which does not occur to all the other objects in the photo since they are stars). After his discovery on this date, he observes for about a month and announces on March 13, 1930, that he has discovered another planet, which he names Pluto after the god of the nether darkness. From its discovery until 2006, Pluto was considered the ninth planet in our solar system, but in 2006, Pluto's status was changed to a dwarf planet by the International Astronomical Union.

1931 Wolfgang Pauli (1900–1958), Austrian-American physicist, posits the existence of an uncharged particle (a neutrino) with little or no mass that is carried away from an atomic nucleus when a beta particle is emitted. His prediction is proved correct in 1955 when a neutrino is finally detected by Reines and Cowan. The uncharged particle is named "neutrino" in 1932 by the Italian-American physicist Enrico Fermi (1901–1954).

1931 Bernard-Ferdinand Lyot (1897–1952), French astronomer, attaches a movie camera to his newly-invented coronagraph and obtains the first moving images of the complex activity of the sun.

1931 Bruno Benedetto Rossi (1905–1993), Italian astronomer, demonstrates the enormous energies of cosmic ray particles as he shows how they can penetrate more than a yard of solid lead. He also discovers the phenomenon of cascade showers, where a high-energy particle hits a nucleus in the upper atmosphere and generates a shower of secondary particles that in turn create even more impacts.

1931 First controlled clinical studies on the use of marihuana are conducted on American soldiers in Panama. The study determines that the drug is not addictive, produces no persistent neurological or mental changes, and is used mainly by men who are incompetent soldiers.

1931 First synthetic fiber is made by a group headed by American chemist Wallace Hume Carothers (1896–1937).

1931 Francis C. Wood and Charles C. Woolferth, both Americans, first demonstrate the use of precordial leads (electrodes directly over the heart) for electrocardiograms.

1931 Harold Clayton Urey (1893–1981), American chemist, discovers deuterium, one of the heavy isotopes of hydrogen.

1931 Harold Spencer Jones (1890–1960), English astronomer, begins a prolonged measurement of the parallax of the asteroid Eros (using fourteen observatories in nine countries) to obtain the distance of the sun from Earth. In 1942 he finally announces the result as 93,005,000 miles. This generally correct figure is not improved upon until the late 1950's when radar is used.

1931 Joseph Needham (1900–1995), English biochemist, publishes his landmark work, *Chemical Embryology*, which shows the relation of biochemistry and embryology and both founds chemical embryology and lays the foundations for modern molecular biology.

1931 Julius Arthur Nieuwland (1878–1936), Belgian-American chemist, develops neoprene, the first successful synthetic rubber.

1931 Karl Bosch (1874–1940), German chemist, and Friedrich Karl Rudolph Bergius (1884–1949), German chemist, are awarded the Nobel Prize for chemistry for their contributions to the invention and development of chemical high pressure methods.

1931 Karl Guthe Jansky (1905–1950), American radio engineer, first detects radio waves

coming from outer space and founds radio astronomy. Once astronomers learn to receive and interpret these microwaves (the shortest radio waves) that can penetrate through dust clouds, they realize they have a window to phenomena that ordinary telescopes could never see.

1931 Kenneth Merrill Lynch, American pathologist, reports what is believed to be the first fatal case of asbestosis in the United States.

1931 Linus Carl Pauling (1901–1994), American chemist, develops his theory of "resonance," which explains many phenomena in organic chemistry.

1931 Otto Heinrich Warburg (1883–1970), German biochemist, is awarded the Nobel Prize for physiology or medicine for his discovery of the nature and mode of action of the respiratory enzyme.

1931 Robert Andrews Millikan (1868–1953), American physicist, proposes his hypothesis on cosmic rays, saying that they are a form of electromagnetic radiation, and that they originate on the outskirts of the universe where matter is being created. He calls it the "birth cry" of matter. His theories do not hold up for long.

1931 Sewall Wright (1889–1988), American geneticist, presents the first useful picture of genetics and its role in evolution.

1931 Sewall Wright (1889–1988), American geneticist, publishes his *Evolution in Mendelian Populations.* This book, along with Fisher's *The Genetical Theory of Natural Selection* (1930), constitutes the mathematical foundation of population genetics.

1931 The first, albeit imperfect, electron microscopes begin to be developed.

1931 Phoebus A. Levene (1869–1940) summarizes his work on the chemical nature of the nucleic acids. His analyses of nucleic acids seems to support the hypothesis known as the tetranucleotide interpretation, which suggests that the four bases were present in equal amounts in DNAs from all sources. This indicated that DNA was a highly repetitious polymer that was incapable of generating the diversity that would be an essential characteristic of the genetic material.

1932 Carl David Anderson (1905–1991), American physicist, studies cosmic rays using a cloud chamber he devises and discovers the positron (a positively charged electron). This is the positively charged electron that Paul Dirac's mathematics had earlier suggested, and it is the first form of antimatter to be discovered.

1932 John Hasbrouck Van Vleck (1899–1980), American physicist, publishes *The Theory of Electrical and Magnetic Susceptibility*, in which he offers his theory on the magnetic properties of atoms in light of quantum mechanical theory. He is regarded as the father of modern magnetism.

1932 Werner Karl Heisenberg (1901–1976), German physicist, wins the Nobel Prize for physics for the creation of quantum mechanics, the application of which leads to the discovery of the allotropic forms of hydrogen.

1932 Alexander Yevgenevi Fersmann (1843–1945), Russian mineralogist, makes the first systematic collection and analysis of soil and weathered rock samples for metalometric surveying.

1932 Charles Scott Sherrington (1857–1952), British physiologist, makes major discoveries of inborn reflexes and shows that the central nervous system involves the integration of several different "levels."

1932 Charles Scott Sherrington (1857–1952), English neurologist, and Edgar Douglas Adrian (1889–1977), English physiologist, are awarded the Nobel Prize for physiology or medicine for their discoveries regarding the functions of the neurons.

1932 Edwin Herbert Land, American inventor, prepares the first synthetic substance that will polarize light (refract light the way a crystal does). His Polaroid Corporation soon dominates the prism-making industry and makes safety glass and spectacles.

1932 Gerhard Domagk (1895–1964), German bacteriologist, discovers the antibacterial effects of prontosil, the first of the sulfonamide drugs.

1932 Hans Adolf Krebs (1900–1981), German-British biochemist, first describes and names the citric acid cycle (Krebs cycle).

1932 Irving Langmuir (1881–1957), American chemist, is awarded the Nobel Prize for chemistry for his discoveries and investigations in surface chemistry.

1932 John Howard Northrop, American biochemist, crystallizes trypsin, a protein-splitting digestive enzyme of pancreatic secretions.

1932 Pentti Eelis Eskola (1883–1964), Finnish petrologist, describes the principles involved in the metamorphism and metasomatism of rocks (the structural and chemical changes in rocks).

1932 Rupert Wildt (1905–1976), German-American astronomer, successfully identifies certain absorption bands in the spectrum of Jupiter as being ammonia and methane. Although his speculation about the clouds of Venus and the composition of other planets are incorrect, his pre-space age work makes him a pioneer in planetary studies.

1932 Walter Sydney Adams (1876–1956), American astronomer, and colleague T. Dunham continue Adam's spectroscopic work and show that the atmosphere of Venus is rich in carbon dioxide. This is the first substance to be detected spectroscopically in the atmosphere of Venus.

1932 Aldous Huxley (1894–1963) publishes the novel *Brave New World,* which presents a dystopian view of genetic manipulations of human beings.

1932 Barbara McClintock (1902–1992) demonstrates that a single exchange within the inversion loop of a paracentric inversion heterozygote in maize generates an acentric and a dicentric chromatid.

1932 Theophilus S. Painter (1889–1969) demonstrates the value of the giant salivary gland chromosomes of *Drosophila* for cytogenetic studies.

1932 William J. Elford and Christopher Howard Andrewes (1896–1988) develop methods of estimating the sizes of viruses by using a series of membranes as filters. Later studies prove that the viral sizes obtained by this method were comparable to those obtained by electron microscopy.

1932 James Chadwick (1891–1974), English physicist, announces his discovery of the neutral particle (with no charge) he calls the neutron. It is this discovery that offers atomic scientists an efficient "bullet" to initiate nuclear reactions. It is the most useful particle for initiating nuclear reactions; it works well because it does not have a charge like protons and electrons and is not repelled by either the nucleus or the orbital electrons in an atom.

1932 John Douglas Cockcroft (1897–1967), English physicist, and Irish physicist Ernest Thomas Sinton Walton (1903–1995), use their new particle accelerator to bombard lithium and produce two alpha particles (having combined lithium and hydrogen to produce helium). This is the first nuclear reaction that has been brought about through the use of artificially accelerated particles and without the use of any form of natural radioactivity. This proves highly significant to the creation of an atomic bomb.

1932 Eugene Paul Wigner (1902–1995), Hungarian-American physicist, introduces the concept of invariance under time reversal into quantum mechanics.

1933 Erwin Schrodinger (1887–1961), Austrian physicist, and Paul Adrien Maurice Dirac (1902–1984), English physicist, win the Nobel Prize for physics for their discovery of new and productive forms of the atomic theory (wave mechanics).

1933 Christopher Howard Andrewes (1896–1988), English pathologist, Wilson Smith (1897–1965), English bacteriologist and virologist, and Patrick Playfair Laidlaw (1881–1940), English physician, demonstrate the viral nature of the human influenza agent by transmitting it to a ferret and then transferring the virus onto a suitable culture medium.

1933 Donald Howard Menzel (1901–1976), American astronomer, discovers oxygen in the sun's corona.

1933 First blood bank in the United States is founded by E.W. Flosdorf and S. Mudd

1933 Glbert Newton Lewis (1875–1946), American chemist, is the first to prepare a sample of water in which all the hydrogen atoms consist of deuterium (the heavy hydrogen isotope). Called "heavy water," this will later play an important role in the production of the atomic bomb.

1933 Mycological Society of America is first founded.

1933 The first total pneumonectomy (extirpation of the lung) for cancer is conducted by American surgeon Evarts Ambrose Graham (1883–1957).

1933 Thomas Hunt Morgan (1866–1945), American geneticist, is awarded the Nobel Prize for physiology or medicine for his discoveries concerning the role played by the chromosome in heredity.

1933 Enrico Fermi (1901–1954), Italian-American physicist, develops a theory of beta decay that uses Pauli's "neutrino" as part of its explanation.

1934 Enrico Fermi (1901–1954), Italian-American physicist, bombards uranium with neutrons and obtains not only a new element, number 93, but also a number of other products he is unable to identify. What he eventually discovers is that he has not only created the first synthetic element, but that he has also produced the first nuclear fission reaction.

1934 Frédéric Joliot-Curie (1900–1958) and Irène Joliot-Curie (1897–1956), husband-and-wife team and both French physicists, discover what they call "artificial radioactivity." They bombard aluminum and produce a radioactive form of phosphorus. They soon learn that radioactivity is not only confined to heavy elements like uranium, but that any element can become radioactive if the proper isotope is prepared. For producing the first artificial radioactive element they win the Nobel Prize in chemistry the next year.

1934 Leo Szilard (1898–1964), Hungarian-American physicist, first conceives of the idea of a nuclear chain reaction (in which a neutron induces an atomic breakdown, which releases two neutrons, which break down two more atoms, and so on). Although his method uses beryllium rather than uranium and would be impractical, it is correct in principle. He keeps it a secret, foreseeing its importance in making nuclear bombs, but it is soon discovered by Otto Hahn and Fritz Strassman.

1934 Marcus Laurence Oliphant (1901–2000), Australian physicist, discovers tritium, the radioactive isotope of hydrogen. This leads eventually to hydrogen fusion and the hydrogen bomb.

1934 Pavel Alekseevich Cherenkov (c.1904–1990), Russian physicist, discovers that a high-energy particle passing through a medium like water may exceed the speed of light in another medium, and when it does it throws back a "wake" of light. This comes to be known as the Cherenkov effect.

1934 Arnold O. Beckman (1900–2004) invents the pH meter, which uses electricity to accurately measure a solution's acidity or alkalinity.

1934 Bruno Benedetti Rossi (1905–1993), Italian-American physicist, conducts an experiment on cosmic rays that demonstrates the majority of cosmic-ray particles are positively charged.

1934 Carl Peter Henrik Dam (1895–1976), Danish biochemist, discovers Vitamin K and finds it to be a factor in blood clotting.

1934 Fritz Zwicky (1898–1974), Swiss-American astronomer, and Walter Baade (1893–1960), German-American astronomer, propose that two types of exploding stars occur. Supernovas explode all at once in a flash and fade out, while novas sort of puff away and usually return to their original brightness. Their research indicates that in any given galaxy, only two or three supernovas occur every thousand years.

1934 George Hoyt Whipple (1878–1976), George Richards Minot (1885– 1950), and William Parry Murphy (1892–1987), all American physicians, are awarded the Nobel Prize for physiology or medicine for

their discoveries concerning liver therapy in cases of anemia.

1934 Harold Clayton Urey (1893–1981), American chemist, is awarded the Nobel Prize for chemistry for his discovery of heavy hydrogen.

1934 J.P. Lent, American biochemist, discovers coumarin in spoiled clover and determines that it acts as an anticoagulant.

1934 John Desmond Bernal (1901–1971), English physicist, makes the first x-ray crystallography of a protein.

1934 L.D. Felton discovers the phenomenon of immunization paralysis due to excessive antigens. This condition is later called immunization tolerance and will become a central problem for future transplants.

1934 Leo Szilard (1898–1964), Hungarian-American physicist, and T.A. Chambers discover that in producing atoms with high energy levels, nuclear transformations are followed by chemical effects (the breaking of bonds). This gives birth to the chemistry of excited states or hot-atom chemistry.

1934 Philipp Ellinger (1888–1952), German biochemist, and Walter Koschara discover Vitamin B_2 (riboflavin) and establish its chemical formula.

1934 Walter Norman Haworth (1883–1950), English chemist, first synthesizes vitamin C, which he names "ascorbic acid."

1934 George Wells Beadle (1903–1989), working with Boris Ephrussi (1901–1971), in collaboration with A. Kuhn and A. Butenandt, work out the biochemical genetics of eye-pigment synthesis in *Drosophila* and *Ephestia*.

1934 J.B.S. Haldane (1892–1964) presents the first calculations of the spontaneous mutation frequency of a human gene.

1935 Hideki Yukawa (1907–1981), Japanese physicist, posits a theory of nuclear forces that correctly predicts the existence of mesons, transient particles with masses between those of electrons and protons.

1934 John Marrack begins a series of studies that leads to the formation of the hypothesis governing the association between an antigen and the corresponding antibody.

1935 Arthur Jeffrey Dempster (1886–1950), Canadian-American physicist, discovers the rare isotope uranium-235. It is this isotope that will undergo fission and be used to build an atomic bomb.

1935 James Chadwick (1891–1874), English physicist, wins the Nobel Prize for physics for his discovery of the neutron.

1935 Lev Davidovich Landau (1908–1968), Russian physicist, pioneers the mathematical treatment of magnetic domains. Within these small regions in substances like iron, all the atomic magnets are lined up in the same direction, making for ferromagnetism, the strongest type of magnetism.

1935 Patrick Maynard Stuart Blackett (1897–1974), English physicist, demonstrates how when gamma rays pass through lead, they sometimes disappear and give rise to a positron and an electron. This is the first demonstrable case of the conversion of energy into matter and as such, is a confirmation of Einstein's famous $E = mc^2$ equation.

1935 António Caetano de Abreu Freire Egas Moniz (1874–1955), Portuguese surgeon, performs the first lobotomy. This operation, which severs the patient's prefrontal lobes of the brain, opens a new field called psychosurgery. It is usually employed as a last resort for severely disturbed patients. After reports of abuse and concerns with its aftereffects, and the discovery of tranquilizers and other mind-affecting drugs, it eventually is discredited and discarded.

1935 B.A. Adams and E. Leighton develop ion-exchange resins. These organic compounds are synthetically polymerized and are used in industry and chemical analysis to remove, separate, or concentrate certain other elements.

1935 Bengt Georg Daniel Strömgren (1908–1987), Swedish astrophysicist, formulates his theory about the internal structure of stars and later becomes a pioneer in the field of gas clouds in space.

1935 Carl David Anderson (1905–1991), American physicist, continues his cosmic ray research using his cloud chamber and dis-

covers a particle that is 130 times more massive than an electron but less than that of a proton. He calls the new particle a "meson."

1935 Charles Francis Richter, American geophysicist, first introduces the Richter scale, which becomes a widely used method of measuring the magnitude of earthquakes. He uses a torsion pendulum seismograph that registers on a scale that is arranged so that each increase of one unit represents a tenfold increase in the magnitude of the earthquake.

1935 Edward Adelbert Doisy (1893–1986), American biochemist, first isolates estrogen directly from ovarian tissue.

1935 Ernst Laqueur (1880–1947), Dutch pharmacologist, and colleagues isolate testosterone from the testis.

1935 First hospital for drug-addicted patients is founded in Lexington, Kentucky.

1935 Frédéric Joliot-Curie (1900–1958), French physicist, and his wife Irène Joliot-Curie (1897–1956), French physicist, are awarded the Nobel Prize for chemistry for their synthesis of new radioactive elements.

1935 Gerhard Domagk (1895–1964), German chemist and pathologist, produces the first effective sulphanilamide derivatives. They prove valuable in fighting bacterial infections.

1935 Hans Spemann (1869–1941), German zoologist, is awarded the Nobel Prize for physiology or medicine for his earlier work, which led to his discovery of the effect now known as embryonic induction. This is the influence exercised by various parts of the embryo that directs the development of groups of cells into particular tissues or organs.

1935 John Heysham Gibbon, Jr. (1903–1973), American surgeon, demonstrates for the first time that life can be maintained by an external pump acting as an artificial heart. He accomplishes this during surgery on a dog.

1935 John Howard Northrop (1891–1987), American biochemist, crystallizes chymotrypsin, a protein-splitting digestive enzyme of the pancreatic secretions.

1935 K. David and associates first isolate a pure crystalline hormone from testicular material and name it testosterone.

1935 Rudolf Schoenheimer (1898–1941), German-American biochemist, uses radioactive tracers to study metabolic processes. His technique of "tagging" molecules with radioactive isotopes makes it possible to trace the paths of organic substances through animals and plants and revolutionizes metabolic studies.

1935 Wendall Meredith Stanley (1904–1971), American biochemist, discovers that viruses are partly protein-based. His work purifying and crystallizing viruses enables scientists to ascertain the precise molecular structure and the modes of propagation of several viruses.

1935 Wendall Meredith Stanley (1904–1971), American biochemist, first crystallizes a virus (the tobacco mosaic virus).

1935 William Maurice Ewing (1906–1974), American geologist, initiates the seismic study of the ocean floor by his use of explosives. He brings this field into the twentieth century by his use of ultrasound reflection, gravity measurements, and core sampling.

1936 Carl David Anderson (1905–1991), American physicist, discovers the muon. While studying cosmic radiation, he observes the track of a particle that is more massive than an electron but only a quarter as massive as a proton. He initially calls this new particle, which only has a lifetime of a few millionths of a second, a mesotron, but it later becomes known as a muon to distinguish it from Hideki Yukawa's meson.

1936 Eugene Paul Wigner, Hungarian-American physicist, proposes the theory of neutron absorption, which comes into play when nuclear reactors are built.

1936 Felix Bloch (1905–1983), Swiss-American physicist, discovers a process by which the magnetic properties of nuclei can be measured. This work leads to the development of a delicate method of chemical analysis called nuclear magnetic resonance.

1936 Victor Franz Hess (1883–1964), Austrian-American physicist, and Carl David Anderson (1905–1991), American physicist, share the Nobel Prize for physics. Hess wins for his discovery of cosmic radiation and Anderson wins for his discovery of the positron.

1936 Charles Snowden Piggot, American chemist and geophysicist, obtains the first core samples of the ocean bottom.

1936 First centrifuge to study acceleration effects on the human body is built by Harry G. Armstrong (1899–1983) and John W. Heim of the United States.

1936 First non-organic agent (methylene blue) shown to mimic the embryologic organizer (prior to our modern understanding of molecular biology, a chemical component thought capable of—or essential to—organizing and directing the normal sequence of embryological development, e.g., tissue differentiation and organ formation) is described by English biochemist Joseph Needham (1900–1995) and colleagues.

1936 Frank Macfarlane Burnet (1899–1985), Australian immunologist, isolates the first mutant bacteriophages, which are tiny, bacteriolytic viruses that will play a major part in future genetics theory.

1936 Henry Hallett Dale (1875–1968), English biologist, and Otto Loewi (1873–1961), German-American physiologist, are awarded the Nobel Prize for physiology or medicine for their discoveries relating to chemical transmission of nerve impulses.

1936 Herbert McLean Evans (1882–1971), American anatomist and embryologist, and his group first isolate the interstitial cell stimulating hormone (ICSH). Also called luteinizing hormone, it is concerned with the regulation of the activity of the gonads or sex glands and is produced by the pituitary gland.

1936 Perrin Hamilton Long (1899–1965), American physician, and Eleanor Albert Bliss, American bacteriologist, first introduce sulfa drugs in the United States. They conduct studies of prontosil in a series of wide-scale applications.

1936 Peter Joseph William Debye (1884–1966), Dutch-American physical chemist, is awarded the Nobel Prize for chemistry for his contributions to knowledge of molecular structure through his investigations on dipole moments and on the diffraction of x rays and electrons in gases.

1936 Reginald Aldworth Daly (1871–1957), American-Canadian geologist, proposes that submarine canyons found along the continental slopes are created through the erosive action of dense water that contains a high percentage of suspended particles.

1936 Tadeus Reichstein (1897–1996), Polish-Swiss chemist, first isolates what is later named cortisone. Edward Calvin Kendall (1886–1972), American biochemist, also isolates nine related steroid hormones from adrenal cortical extracts, one of which (Compound E) is also cortisone.

1936 Theodosius Dobzhansky (1900–1975) publishes *Genetics and the Origin of Species,* a text considered a classic in evolutionary genetics.

1936 George P. Berry and Helen M. Dedrick report the Shope virus could be "transformed" into myxomatosis/Sanarelli virus. This virological curiosity was variously referred to as "transformation," "recombination," and "multiplicity of reactivation." Subsequent research suggests that it is the first example of genetic interaction between animal viruses, but some scientists warn that the phenomenon might indicate the danger of reactivation of virus particles in vaccines and in cancer research.

1937 Clinton Joseph Davisson (1881–1958), American physicist, and George Paget Thomson (1892–1975), English physicist, win the Nobel Prize for physics for their experimental discovery of the diffraction of electrons by crystals.

1937 Emilio Gino Segrè (1905–1999), Italian-American physicist, and Carlo Perrier search and find the lightest element yet discovered, element number 43. They demonstrate that a sample of molybdenum that has been bombarded with deuterons contains a small amount of the anticipated ele-

ment 43, which Segré names technitium. This is the first element to be prepared artificially that does not exist in nature.

1937 Igor Yevgenyevich Tamm (1895–1971), Russian physicist, offers a theoretical explanation of Cherenkov radiation (the "wake" or electromagnetic radiation caused when electrons accelerate).

1937 Isidor Isaac Rabi (1898–1988), Austrian-American physicist, experiments with molecular beams and finds a method to measure the magnetic properties of atoms and molecules with great accuracy.

1937 Albert Szent-Gyorgyi (1893–1986), Hungarian-American biochemist, is awarded the Nobel Prize for physiology or medicine for his discoveries in connection with the biological combustion processes, with special reference to vitamin C and the catalysis of fumaric acid.

1937 Arne Wilhelm Kaurin Tiselius (1902–1971), Swedish chemist, develops electrophoresis to separate and study proteins and to conduct research on blood. Electrophoresis is the movement of charged particles in suspension or solution, under the influence of an electric field, and his work makes it a practical method for studying protein mixtures.

1937 Bernard-Ferdinand Lyot (1897–1952), French astronomer, takes photographs of the sun's corona that show the corona to be rotating at about the same speed as the solar disc itself.

1937 Bruno Sander (1884–1979), Austrian geologist, devises a microscopic technique that he applies to igneous, sedimentary, and metamorphic rocks to correlate the internal optical structure of crystals with their history of deposition or metamorphism.

1937 Daniel Bovet (1907–1992), Swiss-French-Italian pharmacologist, discovers antihistamines—compounds that neutralize some of the symptoms of allergic reactions. In later years, he also first synthesizes curare and develops a method to use it during surgery as a muscle paralyzer. For his work on both, he wins the Nobel Prize in 1957.

1937 First major blood bank is established by Bernard Fantus (1874–1940) at the Cook County Hospital in Chicago.

1937 First successful allogenic (same species) corneal transplant is conducted by the Russian Vladimir Petrovich Filatov (1875–1956).

1937 George Porter Robb, American physician, and Israel Steinberg first introduce angiocardiography. They devise a method of seeing the chambers of the heart and other large vessels after the injection of a contrast medium.

1937 Grote Reber (1911–2002), American radio engineer, builds the first radio telescope and becomes almost single-handedly responsible for the early development of radio astronomy. By 1942, he completes the first preliminary radio maps of the sky and identifies radio sources that are not stars.

1937 H.S. Jacobs first describes the ability of alloxan (an oxidized product of uric acid) to produce hypoglycemia (in rabbits). This becomes an important new tool in the study of diabetes.

1937 James W. Papez (1883–1958) suggests the name "limbic system" for the old mammalian part of the human brain that produces our emotions.

1937 Lung cancer in cigarette smokers is first described by American surgeons Alton Ochsner (1896–1981) and Michael Ellis DeBakey (1908–), who suggest that smoking causes cancer.

1937 Michael Sveda (1912–1999), American chemist, accidentally discovers a sweet-tasting chemical that is eventually called cyclamate.

1937 National Cancer Institute is established by the U.S. Congress.

1937 Otto Struve (1897–1963), Russian-American astronomer, discovers the presence of interstellar hydrogen, in ionized form, which previously had been extremely difficult to detect.

1937 Richard Benedict Goldschmidt (1878–1958), German-American geneticist, theorizes that the gene is a chemical entity rather than a discrete physical structure.

His theories cause a major reevaluation of the concepts governing the science of genetics.

1937 Sergei Nikolaevich Vernov of Russia establishes the distribution of cosmic rays according to altitude.

1937 The "roentgen" (R) is defined and accepted as a unit of measurement for both x rays and gamma rays. Precise measurement becomes essential in order to develop radiation protection standards.

1937 Walter Norman Haworth (1883–1950), English chemist, is awarded the Nobel Prize for chemistry for his investigations on carbohydrates and vitamin C. Paul Karrer (1889–1971), Swiss chemist, is also awarded the Nobel Prize for chemistry for his investigations on carotenoids, flavins, and vitamins A and B_2.

1937 William Thomas Astbury (1898–1961), English physicist, first obtains information about the structure of nucleic acid by means of x-ray diffraction.

1938 Albert Einstein (1879–1955), German-Swiss-American physicist, and Leopold Infeld (1898–1968), Polish physicist, publish *The Evolution of Physics.* Written for the layman, it becomes extremely popular.

1938 Enrico Fermi (1901–1954), Italian-American physicist, wins the Nobel Prize for physics for his demonstrations of the existence of new radioactive elements produced by neutron irradiation and for his related discovery of nuclear reactions brought about by slow neutrons.

1938 Alan Lloyd Hodgkin (1914–1998) and Andrew Fielding Huxley (1917–), both English physiologists, show that nerve impulse consists of a wave depolarization. Their work eventually leads to the "sodium-pump" discovery.

1938 Albert Hoffman (1906–2008) of Switzerland first synthesizes lysergic acid diethylamide, known as LSD-25. By 1943, Hoffman discovers its potent ability to influence mental processes. It becomes a trendy, mind-altering (and illegal) drug in the 1960s and 1970s.

1938 Corneille-Jean Heymans (1892–1968), Belgian physiologist, is awarded the Nobel Prize for physiology or medicine for the discovery of the role played by the sinus and aortic mechanisms in the regulation of respiration.

1938 Edward Charles Dodds, English chemist, and colleagues discover the first synthetic estrogen (stilboestrol).

1938 Hans Albrecht Bethe (1906–2005), German-American physicist, works out the details of the nuclear mechanisms that power the stars. He describes what becomes known as the Bethe cycle, beginning with the union of a hydrogen nucleus (a proton) with a carbon nucleus. A series of reactions then occur in which the carbon nucleus is regenerated and four hydrogen nuclei are converted to a helium nucleus. Hydrogen is thus the "fuel" of a star and helium is the left-over "ash," with carbon as the catalyst.

1938 Howard W.F. Florey (1898–1968), Austrian-English biochemist, and Ernst Boris Chain (1906–1979), German-English biochemist, first isolate and purify penicillin (discovered by Alexander Fleming in 1928), making it potentially available for general use.

1938 J. Lempert, American surgeon, introduces the "fenestration" operation for otosclerosis. This new operation cuts an opening into the inner ear to replace the natural opening that is obstructed.

1938 J. Robert Oppenheimer (1904–1967), American physicist, predicts the existence of rapidly rotating neutron stars. Nearly thirty years later they are discovered and called "pulsars."

1938 Nylon is first manufactured by Dupont. It is marketed in 1939.

1938 Richard Kuhn (1900–1967), Austrian-German chemist, first isolates vitamin B_6 (pyridoxine) from skim milk.

1938 Richard Kuhn (1900–1967), Austrian-German chemist, is awarded the Nobel Prize for chemistry for his work on carotenoids and vitamins.

1938 Emory L. Ellis and Max Delbrück (1906–1981) perform studies on phage replica-

tion that mark the beginning of modern phage work. They introduce the "one-step growth" experiment, which demonstrates that after bacteriophages attack bacteria, replication of the virus occurs within the bacterial host during a "latent period," after which viral progeny are released in a "burst."

1938 Teflon is accidentally discovered in the residue of refrigerant gases by the labs of the Dupont Company. After the war, they discover it is insoluble in everything, completely water-resistant, a good electrical insulator, heat-resistant, and, most importantly, fat will not stick to it.

1938 Adriaan van Maanen (1884–1946), Dutch-American astronomer, discovers a new type of variable star called a flare whose brightness varies at intervals of only a few minutes.

1938 Mass hysteria among American radio listeners is caused by a dramatic reenactment of H.G. Wells' (1866–1946) novel *War of the Worlds.* American actor, writer, and director George Orson Welles (1915–1985) leads many to believe that a "gas raid from Mars" is actually happening.

1938 A major zoological discovery is made when a large fish, *Latimeria chalumnal*, is caught off the eastern coast of South Africa.

1939 Television debuts to the public at the World's Fair.

1939 Ernest Orlando Lawrence (1901–1958), American physicist, wins the Nobel Prize for physics for the invention and development of the cyclotron and for results obtained with it, especially with regard to artificial radioactive elements.

1939 John Ray Dunning (1907–1975), American physicist, is the first to experimentally confirm Lise Meitner's theory on uranium fission.

1939 Leo Szilard (1898–1964), Hungarian-American physicist, and Canadian-American physicist Walter Henry Zinn confirm that fission reactions (nuclear chain reactions) can be self-sustaining using uranium.

1939 Niels Hendrik David Bohr (1885–1962), Danish physicist, proposes a liquid-drop model of the atomic nucleus and offers his theory of the mechanism of fission. His prediction that it is the uranium-235 isotope that undergoes fission is proved correct shortly after work begins in the United States on an atomic bomb.

1939 Richard Brooke Roberts (1910–1980), American biophysicist, discovers that uranium fission does not release all the neutrons it produces at one time. This phenomenon of "delayed neutrons" eventually proves to be an important element in the safety of nuclear reactors.

1939 Adolf Friedrich Johann Butenandt (1903–1994), German chemist, is awarded the Nobel Prize for chemistry for his work on sex hormones. Leopold Stephen Ruzicka (1887–1976), Croatian-Swiss chemist, is also awarded the Nobel Prize for chemistry for his work on polymethylenes and higher terpenes.

1939 First attempts at ultramicrotomy (superthin sections for microscopic analysis) are made.

1939 Gerhard Domagk (1895–1964), German biochemist, is awarded the Nobel Prize for physiology or medicine for the discovery of the antibacterial effects of prontosil.

1939 Hannes Olof Gösta Alfvén (1908–1995), Swedish astrophysicist, publishes a theory of magnetic storms and the aurora. He goes on to do pioneering theoretical research in the field of magnetohydrodynamics (the study of conducting fluids and their interaction with magnetic fields).

1939 Johannes Friedrich Karl Holtfreter, German biologist, first shows selective reaggregation of cultured cells.

1939 Linus Carl Pauling (1901–1994), American chemist, publishes *The Nature of the Chemical Bond*, a classic work that becomes one of the most influential chemical texts of the twentieth century.

1939 Marcus Laurence Oliphant (1901–2000), Australian physicist, Paul Harteck (1902–1985), Austrian chemist, and Ernest Rutherford (1871–1937), English physicist, discover tritium, one of the heavy isotopes of hydrogen.

1939 Marguerite Perey (1909–1975), French chemist, first isolates element number 87 from among the breakdown products of uranium. She names it "francium" after her country.

1939 Paul Hermann Müller (1899–1965), Swiss chemist, discovers the insect-repelling properties of DDT (dichlorodiphenyltrichloroethane)—which was first synthesized in 1873. It proves extremely effective for agricultural purposes and in controlling typhus epidemics, but is eventually determined to be a powerfully harmful environmental pollutant.

1939 Subramanyan Chandrasekhar (1910–1995), Indian-American astronomer, calculates models for white dwarf stars of different masses and determines there is a definite limit to the amount of mass dwarf stars can have. Any dwarf that has more than 1.5 times the mass of the sun (called the Chandrasekhar mass or Chandrasekhar limit) will be crushed by its own gravity. This is what happens to a supernova.

1939 Walter Maurice Elsasser (1904–1991), German-American geophysicist, suggests that Earth's rotation sets up eddy currents in its molten core, which creates Earth's magnetic field.

1939 William Maurice Ewing (1906–1974), American geologist, takes the first deep-sea photographs.

1939 Moses Kunitz reports the purification and crystallization of ribonuclease from beef pancreas.

1939 Richard E. Shope reports that the swine influenza virus survives between epidemics in an intermediate host. This discovery was an important step in revealing the role of intermediate hosts in perpetuating specific diseases.

1939 Howard W.F. Florey (1898–1968), Austrian-English biochemist, and Ernst Boris Chain (1906–1979), German-English biochemist, refine the purification of penicillin, allowing the mass production of the antibiotic.

1939 Lise Meitner (1878–1968), Austrian-Swedish physicist, and Otto Robert Frisch (1904–1979), Austrian-British physicist, suggest the theory that uranium breaks into smaller atoms when bombarded. Meitner offers the term "fission" for this process.

1939 Otto Hahn (1870–1968), German physical chemist, and Fritz Strassman (1902–1980), German chemist, publish results of research in which they first observe that fission reactions can be self-sustaining because of the chain reaction that occurs. This discovery eventually makes the construction of an atomic bomb feasible.

1939 Publication of the first detailed scientific paper suggesting that the endpoint of massive stars that have exhausted their nuclear sources of energy must be an infinitely collapsed object from which even light could not escape, i.e., what is now called a black hole, by Robert Oppenheimer and Snyder.

1940 Donald William Kerst (1911–1993), American physicist, builds the first betatron. This particle accelerator spins electrons (a cyclotron spins protons) in a circle to study high-energy particles.

1940 Georgii Nikolaevich Flerov (1913–1990), Russian physicist, discovers the spontaneous fission of heavy nuclei. He learns that uranium does not undergo fission only when bombarded with neutrons, but that it also does so naturally or spontaneously, although extremely slowly.

1940 Philip Hauge Abelson (1913–2004), American physical chemist, proposes the gas diffusion process for separating uranium-235 from uranium-238.

1940 Ángel H. Roffo (1882–1947) offers the first data on lung cancer in smokers.

1940 Dale Raymond Corson (1914–), American physicist, K.R. McKenzie, and Emilio Gino Segrè (1905–1989), Italian-American physicist, artificially prepare element number 85, asatine.

1940 David Tressel Griggs (1911–1974), American geophysicist, studies the experimental flow of rocks under conditions favoring crystallization. His later experimental work provides the basis for understanding stress-strain relations in earth materials.

1940 Edwin Mattison McMillan (1907–1991), American physicist, and Philip Hauge Abelson (1913–2004), American physical chemist, prepare the first of the transuranic (a higher atomic number than uranium) elements, neptunium, element 93.

1940 George Wells Beadle (1903–1989), American geneticist, and Edward Lawrie Tatum (1909–1975), American biochemist, establish the formula "One gene = one enzyme." This discovery that each gene supervises the production of only one enzyme lays the foundation for the DNA discoveries to come.

1940 Harold Jeffreys (1891–1989), English astronomer, and Keith Edward Bullen (1906–1976), New Zealand mathematician, publish what become the standard tables of travel times for earthquake waves. They come to be known as the "J-B tables."

1940 Karl Landsteiner (1868–1943), Austrian-American physician, and Alexander S. Wiener (1907–1976) discover the Rhesus-factor in blood. This discovery of the Rh blood groups proves to have a connection with a disease of newborns called erythroblastosis fetalis.

1940 Martin David Kamen (1913–2002), Canadian-American biochemist, discovers the radioactive isotope carbon-14. With a half-life of 5,700 years, it becomes highly useful for biochemical and archaeological uses such as dating ancient artifacts and sites.

1940 Vincent Du Vigneaud (1901–1978), American biochemist, identifies a compound called biotin as being what previously had been known as vitamin H.

1940 Kenneth Mather (1911–1990) coins the term "polygenes" and describes polygenic traits in various organisms.

1940 Ernest Boris Chain (1906–1979) and Edward P. Abraham (1913–1999) detail the inactivation of penicillin by a substance produced by *Escherichia coli.* This is the first bacterial compound known to produce resistance to an antibacterial agent.

1940 Helmuth Ruska obtains the first electron microscopic image of a virus.

1941 Peter Leonidovich Kapitza (1894–1984) publishes his research on liquid helium, describing the point at which it becomes a superfluid. He coins the term superfluidity to describe its incredible conductivity.

1941 Alfred Otto Carl Nier (1911–1994), American physicist, introduces the use of the mass spectrometer to measure the lead isotope ratio. This allows for much more rapid geological dating than the older method of determining atomic weight.

1941 Arnold O. Beckman (1900–2004) invents the spectrophotometer. This instrument measures light at the electron level and can be used for many kinds of chemical analysis.

1941 Glenn Theodore Seaborg (1912–1999), American physicist, and his colleagues prepare the transuranic element number 94, plutonium.

1941 H.K. Mitchell isolates pteroylglutamic acid from spinach, naming it folic acid.

1941 I.G. Farbenindustrie of Germany begins the production of polyurethane.

1941 L.D. Goodhue and W.N. Sullivan, both of the United States, invent an aerosol spray or "bug bomb" for applying insecticides.

1941 Norman M. Gregg of Australia discovers that rubella during pregnancy can cause congenital abnormalities. Children of mothers who had rubella (German measles) during their pregnancy are found to suffer from blindness, deafness, and heart disease.

1941 Penicillin is first used to treat pneumonia.

1941 R. Sherr, Kenneth Thompkins Bainbridge (1904–1996), American physicist, and H.H. Anderson produce artificial gold from mercury.

1941 The anticoagulant drug dicumarol is first identified and synthesized by American biochemists Mark Arnold Stahmann, Karl Paul Link (1901–1978), and C.F. Huebner.

1941 George Wells Beadle (1903–1989) and Edward Lawrie Tatum (1909–1975) publish their classic study on biochemical genetics titled *Genetic Control of Biochemical Reactions in Neurospora.* Beadle and

Tatum irradiate red bread mold *Neurospora* and prove that genes produce their effects by regulating particular enzymes. This work leads to the one gene–one enzyme theory.

1941 Antibody to diphtheria is produced.

1942 C. Auerbach in England discovers the first chemical mutagen called yperite. The identification of this and other substances that can cause structural changes in genes offer science a new tool for investigating the structure of genes via induced mutations.

1942 Choh Hao Li (1913–1987), American chemist and endocrinologist, and George Sayers isolate ACTH (adrenocorticotropic hormone). Formed by the pituitary gland, this hormone regulates the activity of the adrenal gland.

1942 Harvard Univeristy scientists develop an inexpensive gelling agent using naphthionic acid and palmitic acid. They call the new compound "napalm" and mix it with gasoline. It is later adapted for military purposes and serves as a deadly weapon, clinging to whatever it touches and burning ferociously.

1942 Klinefelter's syndrome is first described by American physician Henry E. Klinefelter, Jr., with colleagues Edward C. Reifenstein and endocrinologist Fuller Albright (1900–1969). This congenital endocrine condition is the result of testicular failure.

1942 R.E. Slade points out the insecticidal effect of hexachlorocyclohexane (also known as lindane). The earlier introduction of "bug bombs" or aerosol sprays spurs insecticide production.

1942 The U.S. National Research Council and the Geological Society of America jointly issue an exhaustive bibliography on military geology and geography.

1942 Jules Freund (1890–1960) and Katherine McDermott identify adjuvants (e.g., paraffin oil) that act to boost antibody production.

1942 Salvador E. Luria (1912–1991) and Max Delbrück (1906–1981) demonstrate statistically that inheritance of genetic characteristics in bacteria follows the principles of genetic inheritance proposed by Charles Darwin (1809–1882). For their work, the two (along with Alfred Day Hershey [1908–1997]) are awarded the 1969 Nobel Prize for physiology or medicine.

1942 Selman Waksman (1888–1973) suggests that the word "antibiotics" be used to identify antimicrobial compounds that are made by bacteria.

1942 J.S. Hey, British radio astronomer, and colleagues discover that the sun emits radio waves. This occurs during World War II, and Hey and his group believe at first that what they are detecting is German jamming of their radio transmitters.

1942 Frank Harold Spedding (1902–1984), American physicist, develops the necessary methods to produce pure uranium in very large quantities for the U.S. atomic bomb effort. Spedding's laboratory produces two tons this month, to be used for the first "atomic pile."

1942 Enrico Fermi (1901–1954), Italian-American physicist, heads a Manhattan Project team at the University of Chicago that produces the first controlled chain reaction in an atomic pile of uranium and graphite. With this first self-sustaining chain reaction, the atomic age begins.

1943 First operational nuclear reactor is activated at the Oak Ridge National Laboratory in Oak Ridge, Tennessee.

1943 J. Robert Oppenheimer (1904–1967), American physicist, is placed in charge of U.S. atomic bomb production at Los Alamos, New Mexico. He supervises the work of 4,500 scientists and oversees the successful design construction and explosion of the bomb.

1943 Marcus Laurence Oliphant (1901–2000), Australian physicist, proposes a design for a new and very powerful accelerator called a proton synchrotron. These eventually are built and are capable of accelerating protons to fantastic energies.

1943 Otto Stern (1888–1969), German-American physicist, wins the Nobel Prize for physics for his contribution to the development of the molecular ray method

and his discovery of the magnetic moment of the proton.

1943 Carl Ferdinand Cori (1896–1984) and Gerty Theresa Radnitz Cori (1896–1957), Czech-American husband and wife biochemists, first achieve the test-tube synthesis of glycogen and later (1947) win a Nobel Prize for physiology or medicine for their discovery of the role sugar plays in the metabolism of animals.

1943 Carl Keenan Seyfert (1911–1960), American astronomer and astrophysicist, identifies galaxies with very condensed nuclei, now called Seyfert galaxies. They are thought to be highly active, sometimes emitting radio waves, infrared, and even x rays.

1943 Charles Philippe Leblond (1910–2007), French anatomist (alone), and Saul Hertz, American physician, and Arthur Roberts, American physicist, (together) independently introduce radioactive iodine for the assessment of Graves's disease (hyperthyroidism) and later for its treatment.

1943 DDT (dichlorodiphenyltrochloroethane) is given its first major field test by the U.S. Army in Naples, Italy, where it stops a typhus epidemic.

1943 Dow Corning of the United States begins production of the first silicons.

1943 Georg von Hevesy (1885–1966), Hungarian-Danish-Swedish chemist, is awarded the Nobel Prize for chemistry for his work on the use of isotopes as tracers in the study of chemical processes.

1943 Henrik Carl Peter Dam (1895–1976), Danish biochemist, is awarded the Nobel Prize for physiology or medicine for his discovery of vitamin K. Edward Adelbert Doisy (1893–1986), American biochemist, is awarded the Nobel Prize for physiology or medicine for his discovery of the chemical nature of vitamin K.

c. 1943 Lars Onsager (1903–1976), Norwegian-American chemist, works out the theoretical basis for the gaseous-diffusion method of separating uranium-235 from the more common uranium-238. This is essential for producing nuclear bombs or nuclear power.

1943 Many strategic areas in the United States are mapped topographically for the first time on the basis of airplane photographs.

1943 Penicillin is first used on a large scale by the U.S. Army in the North African campaigns. Data obtained from these studies show that early expectations for the new drug are correct, and the groundwork is laid for the massive introduction of penicillin into civilian medical practice after the war.

1943 Walter Baade (1893–1960), German-American astronomer, discovers there are two populations of stars. One he classifies as Population I, made up of younger stars found in the spiral arms of galaxies, and Population II, older stars found in the nuclei of spiral galaxies. His classification is a milestone in the history of stellar astronomy.

1944 Isidor Isaac Rabi (1898–1988), Austrian-American physicist, wins the Nobel Prize for physics for his resonance method for recording the magnetic properties of atomic nuclei.

1944 Sin-Itiro Tomonaga (1906–1979), Japanese physicist, works out the theoretical basis for quantum electrodynamics independently of American physicists Richard Philips Feynman (1918–1988) and Julian Seymour Schwinger (1918–1994), who also work independently of one another. This method allows for the behavior of electrons to be worked out with far greater precision than before. It also leads to the formulation of quantum electrodynamics.

1944 Archer John Porter Martin (1910–2002) and Richard Laurence Millington Synge (1914–1994), both English biochemists, first develop the technique of paper chromatography for which they share a Nobel Prize in 1952. Their method of using porous filter paper to separate and identify the nearly-identical but different types of amino acids proves an instant success. With this method of being able to separate very closely related compounds, others are able to determine the number of particular amino acids in protein molecules, and the

scheme of photosynthesis is eventually worked out.

1944 Carl Friedrich Weizsöcker, German astronomer, proposes a variation of the old nebular hypothesis for the origin of the solar system. His theory says the solar system evolved out of a system of vortices and implies that the universe is rich in planetary systems.

1944 First compilation of worldwide epidemiological, sanitary, and public health data is published by the U.S. Army. Titled *Global Epidemiology: A Geography of Disease and Sanitation*, this work begins the modern concept of global medicine.

1944 Gerard Peter Kuiper (1905–1973), Dutch-American astronomer, discovers absorption bands from methane in the spectrum of Titan, a satellite of Jupiter. This is the first discovery of a satellite possessing an atmosphere.

1944 Glenn Theodore Seaborg (1912–1999), American physicist, and colleagues prepare the transuranic elements americum (number 95) and curium (number 96).

1944 Grote Reber (1911–2002), American radio engineer, using his own 32.8-foot (10-m) orientable parabolic reflector, draws a radio map of the galaxy showing three zones of very strong radio emission. With this, extragalactic radio astronomy is born.

1944 H.A. Hyde and D.A. Williams first propose the word "palynology" to replace the cumbersome and restrictive term "pollen analysis." Palynology is the study of acid-resistant microscopic plant and animal remains (such as pollen, algae, fungi, and spores).

1944 Joseph Erlanger (1874–1965) and Herbert S. Gasser (1888– 1963), both American physiologists, share the Nobel Prize for physiology or medicine for their earlier work on the amplification of nerve currents and discoveries relating to the highly differentiated functions of single nerve fibers. They are able to achieve great delicacy of measurement and determine how different fibers in the brain conduct their impulses at different rates.

1944 Leading educational institutions in the West revise their curricula in geology and prepare for the post-war boom in students. The trend in training for applied geology is now toward more emphasis on an engineering background, photogrammetry, and upon the more quantitative phases of the subject.

1944 Oswald T. Avery (1877–1955), Colin M. MacLeod (1909–1972), and Maclyn McCarty (1911–2005) publish a landmark paper on the pneumococcus transforming principle. The paper is titled "Studies on the chemical nature of the substance inducing transformation of pneumococcal types." Avery suggests that the transforming principle seems to be deoxyribonucleic acid (DNA), but contemporary ideas about the structure of nucleic acids suggest that DNA does not possess the biological specificity of the hypothetical genetic material.

1944 Otto Hahn (1879–1968), German physical chemist, is awarded the Nobel Prize for chemistry for his discovery of the fission of heavy metal.

1944 Robert Burns Woodward (1917–1979), American chemist, and William von Eggers Doering (1917–) first synthesize quinine using no intermediate compounds.

1944 Selman A. Waksman (1888–1973), Russian-American microbiologist, discovers the action of strepomycin against the tubercule bacillus. This leads to the discovery of other antibiotics, a word coined by Waksman.

1944 Stanley F. Erpf of the United States develops an artificial eye made of acrylic plastic. It resembles a human eye and is unbreakable.

1944 New techniques and instruments, such as partition chromatography on paper strips and the photoelectric ultraviolet spectrophotometer, stimulate the development of biochemistry after World War II. New methodologies make it possible to isolate, purify, and identify many important biochemical substances, including the purines, pyrimidines, nucleosides, and nucleotides derived from nucleic acids.

1944 Salvador E. Luria (1912–1991) and Alfred Day Hershey (1908–1997) prove that mutations occur in bacterial viruses, and develop methods to distinguish the mutations from other alterations.

1944 The first German V-1 "buzz bomb" explodes in the center of London. This fairly conventional weapon is a winged subsonic rocket with a pulse-jet engine that operates on gasoline. This missile has a speed of less than 400 mph (643.7 km/h) and a range of 190 miles (305.8 km) while carrying a warhead of 1,988 pounds (901.7 kg). Although more than 8,000 rain down on London during the war, they are inefficient and unreliable and have no real strategic effect.

1944 John von Neumann (1903–1957), Hungarian-American mathematician, visits the Moore School of Engineering for the first time and inspects ENIAC (Electronic Numerical Integrator and Computer). He later will give the computer its first real job, which has to do with a large and complex calculation of the feasibility of a proposed design for the H-bomb.

1944 The U.S. Army extends its support of ENIAC (Electronic Numerical Integrator and Computer) to include a new stored-program computer project called EDVAC (Electronic Discrete Variable Computer).

1944 First successful operation to remedy the "blue baby" syndrome is conducted by American surgeon Alfred Blalock (1899–1964). He uses a technique based on the research of the American pediatric cardiologist Helen Brooke Taussig (1898–1986). Blalock becomes a pioneer in the surgical repair of congenital heart disease.

1945 Vladimir Iosifovich Veksler (1907–1966), Ukrainian physicist, suggests a design for a cyclotron that will allow for relativistic changes in the mass of accelerating particles and therefore achieve greater energies. His ideas are later used to build the synchrocyclotron.

1945 Wolfgang Pauli (1900–1958), Austrian-American physicist, wins the Nobel Prize for physics for his discovery of the Pauli exclusion principle for subatomic particles.

1945 Alexander Fleming (1881–1955), Scottish bacteriologist, Ernst Boris Chain (1906–1979), German-English biochemist, and Howard Walter Florey (1898–1968), Austrian-English pathologist, are awarded the Nobel Prize for physiology or medicine for the discovery of penicillin and its curative effect in various infectious diseases.

1945 American Cancer Society is incorporated.

1945 Artturi Ilmari Virtanen (1895–1973), Finnish biochemist, is awarded the Nobel Prize for chemistry for his research and inventions in agricultural and nutrition chemistry, especially for his fodder preservation method.

1945 Edwin J. Pulaski of the U.S. Army establishes the Surgical Research Unit, which becomes the first American center for the study of burn patients.

1945 First kidney dialysis machine is invented by the Dutch-American Willem J. Kolff. His system keeps patients with kidney failure alive by filtering out urea from their blood.

1945 Guy Henry Faget (1891–1947), American physician, first introduces the drug promin, which proves to be effective against leprosy.

1945 Hendrik Christoffell van de Hulst (1918–2000), Dutch astronomer, conducts theoretical studies on the behavior of cold hydrogen atoms in space and predicts that this hydrogen should be sending out radio emissions at a wavelength of 8.3 inches (21.1 cm). After World War II ends, others search and find this radiation. It becomes especially useful in creating a map of our galaxy, the shape of which is seen as a spiral.

1945 Robert Henry Dicke (1916–1997), American physicist, detects thermal radiation from the moon at radio wavelengths.

1945 William Otis Hotchkiss (1878–1954), American engineer, publishes his *Minerals of Might*, in which he surveys the mineral industry in war and peace and asserts that mineral production during the previous thirty years (1915–1945) was as great

as that during all the earlier history of mankind.

1945 Max Delbrück (1906–1981) organizes the first session of the phage course at Cold Spring Harbor Laboratory. The widely influential phage course, which is subsequently taught for 26 consecutive years, serves as the training center for the first two generations of molecular biologists.

1945 U.S. troops enter the Peenemunde rocket center in Germany and discover completely intact assembly lines of V-1 and V-2 rockets. A special mission is then hastily created to ship all of the rockets to Antwerp, Belgium. From May 22 to May 31 of this year, 341 railroad cars are loaded with about 100 V-2 rockets. They then leave Antwerp via Liberty ships for New Orleans and are finally shipped to the New Mexico desert for tests.

1945 First atomic bomb is successfully detonated by the United States near Almagordo, New Mexico. The experimental bomb generates an explosive power equivalent to between 15 and 20 thousand tons of TNT.

1945 First atomic bomb is dropped on Hiroshima, Japan. This uranium nuclear fission bomb based on uranium-235 weighs 2,000 tons and has an explosive energy of 20,000 tons of TNT. After an equally destructive plutonium bomb is dropped on and destroys Nagasaki, Japan, three days later, Japan surrenders unconditionally on August 14, ending World War II. This is the first use of nuclear power as a weapon.

1946 Abraham Pais (1918–2000), Dutch physicist, and Christian Moller, Danish physicist, conduct research on high energy particles and suggest the name "lepton" for lightweight particles not affected by the strong force.

1946 George Dixon Rochester (1908–2001) and Clifford Charles Butler, English physicists, discover "V particles" in a cloud chamber. The role of these new elementary particles is not understood until Murray Gell-Mann's (1929–) concept of "strangeness" is introduced.

1946 Percy Williams Bridgman (1882–1961), American physicist, wins the Nobel Prize for physics for the invention of an apparatus to produce extremely high pressures and the discoveries made with it in the field of high pressure physics.

1946 Alfred Charles Bernard Lovell (1913–), English astronomer, and colleagues demonstrate that radar echoes can be obtained from daytime meteor showers, which are naturally invisible.

1946 Communicable Disease Center for the United States in established in Atlanta, Georgia.

1946 Edward Mills Purcell (1912–1997), American physicist, discovers nuclear magnetic resonance. This breakthrough becomes widely used to study the molecular structure of materials. It also leads to the field of nuclear medicine, which allows for a sensitive scan of the body to be taken to detect abnormalities.

1946 Fred Hoyle, English astronomer, suggests that the sun was originally a double star and that its companion exploded and formed the planets. He becomes a strong proponent of the steady-state theory of the origin of the universe.

1946 Hermann Joseph Muller (1890–1967), American biologist, is awarded the Nobel Prize for physiology or medicine for the discovery of the production of mutations by means of x-ray irradiation.

1946 J.H. De Witt and Edwin King Stodola, U.S. Army Signal Corps researchers, use the newly-invented radar and obtain radar echoes from the moon. In Hungary, Z. Bay independently achieves the same thing this year.

1946 James Batcheller Sumner (1887–1955), American biochemist, is awarded the Nobel Prize for chemistry for his discovery that enzymes can be crystallized. John Howard Northrop (1891–1987) and Wendell Meredith Stanley (1904–1971), both American chemists, are also awarded the Nobel Prize for chemistry for their preparation of enzymes and virus proteins in a pure form.

1946 Joshua Lederberg (1905–2008), American geneticist, and Edward Lawrie Tatum (1909–1975), American biochemist and geneticist, first demonstrate genetic recombination in *E. coli* bacteria. This intermingling of the genetic material of bacteria greatly expands the type of genetic research that can be done.

1946 Max Delbrück (1906–1981) and W.T. Bailey Jr. publish a paper entitled "Induced Mutations in Bacterial Viruses." Despite some confusion about the nature of the phenomenon in question, this paper establishes the fact that genetic recombinations occur during mixed infections with bacterial viruses. Alfred Day Hershey (1908–1997) and R. Rotman make the discovery of genetic recombination in bacteriophage simultaneously and independently. Hershey and his colleagues prove that this phenomenon can be used for genetic analyses. They construct a genetic map of phage particles and show that phage genes can be arranged in a linear fashion.

1946 John von Neumann (1903–1957), Hungarian-American mathematician, begins work at the Institute for Advanced Study at Princeton, New Jersey, to establish a digital computer project. He is soon joined by Julian Bigelow (1913–2003), American engineer, and American mathematician Herman Heine Goldstine (1913–2004).

1946 First reported detection of a magnetic field in an extrasolar object, namely the Peculiar A-type (or Ap) star, 78 Virginis, by Horace Babcock (1912–2003), using the 100-inch (2.5 m) telescope at the Mount Wilson Observatory, near Pasadena, California.

1946 The Computer Laboratory is established at Manchester University under a grant from the Royal Society.

1946 United States' researchers launch from White Sands, New Mexico, a captured German V-2 rocket carrying a spectroscope to an altitude of 50 miles (80.5 km). It takes an ultraviolet photograph of the solar spectrum. This is the beginning of astronomers' ability to explore space from above Earth's atmosphere.

1946 First synchrocyclotron is built at the University of California at Berkeley.

1946 Igor Vasilevich Kurchativ (1903–1960), Russian physicist, directs the first Soviet self-sustaining reactor into successful operation.

1947 Cecil Frank Powell (1903–1969), English physicist, discovers the pi-meson or pion, a subatomic particle that decays very quickly but carries a strong force.

1947 Dennis Gabor (1900–1979), Hungarian-British physicist and electrical engineer, first conceives of the idea of holography (lensless, three-dimensional photography) and begins to develop its basic techniques. Because available light sources are too weak or too diffuse, he must wait until the 1960 invention of the laser to make his idea commercially feasible.

1947 Edward Victor Appleton (1892–1965), English physicist, wins the Nobel Prize for physics for his investigations of the physics of the upper atmosphere, especially for the discovery of the so-called Appleton layer.

1947 Willis Eugene Lamb, Jr. (1913–2008), American physicist, applies a new method to measure the spectrum lines of hydrogen and finds them different from what was predicted. He finds a splitting of energy levels, called the Lamb shift, that contributes to the development of quantum electrodynamics (QED).

1947 Bart Jan Bok (1906–1983), Dutch-American astronomer, discovers small, dark, circular dust clouds visible against a star background that are now called Bok's globules. He suggests that these are precursors of stars or stars-in-the-making.

1947 Benjamin Minge Duggar (1872–1956), American botanist, discovers the antibiotic aureomycin.

1947 Bernardo Alberto Houssay (1887–1971), Argentinean physiologist, is awarded the Nobel Prize for physiology or medicine for his studies of the pituitary gland and his demonstration of the complex interlocking of hormonal effects, such as the part played by the hormone of the anterior

pituitary lobe in the metabolism of sugar. The Czech-American biochemists Carl F. and Gerty Radnitz Cori (1896–1984 and 1896–1957) also win this year for their earlier work.

1947 Felix Andries Vening Meinesz (1887–1966), Dutch geophysicist, offers his theory concerning convection currents within Earth.

1947 Fritz Albert Lipmann (1899–1986), German-American biochemist, discovers what he calls coenzyme A. This breakthrough in body chemistry leads to a better understanding of the process of metabolism and the production of energy. He wins the Nobel Prize for this in 1953.

1947 John Ehrlich, American biologist, with colleagues Q.R. Bartz, R.M. Smith, D.A. Joslyn, and P.R. Burkholder, discover the antibiotic chloramphenicol, which becomes known as Chloromycetin.

1947 Martin Ryle (1918–1984), English astronomer, identifies Cygnus A as a radio source. This is the first known radio galaxy to be identified.

1947 Robert Robinson (1886–1975), English chemist, is awarded the Nobel Prize for chemistry for his investigations on plant products of biological importance, especially the alkaloids.

1947 Theodore E. Woodward (1914–2005), American physician, reports the first specific cure of typhoid fever with chloramphenicol while in Malaya.

1947 Willard Frank Libby (1908–1980), American chemist, develops the carbon-14 dating technique. Using the knowledge that the isotope carbon-14 is found in all carbon-containing products of life, and that after an organism dies it produces no more carbon-14, he realizes that he has discovered a practical dating technique.

1947 Thomas M. Kilburn (1921–2001) designs and extends the memory storage capacity of the Williams Kilburn tube—an electronic memory storage device—paving the way for stored-program computers.

1947 Hermann J. Muller (1890–1967) coins the term "dosage compensation."

1947 The first piloted aircraft to exceed the speed of sound in level flight is the Bell *X-1*, flown by American aviator Charles Elwood Yeager (1923–). This rocket-powered aircraft is launched or released from a parent aircraft and reaches a speed of 670 mph (1,078 km/h) or Mach 1.015. Mach speed is relative to an airplane's altitude, so that Mach 1.0 at sea level at 59° F (15° C) is 760.98 mph (1224 km/h). In the stratosphere (above 36,089 ft—6.8 miles, or 11 km), Mach 1 is 659.78 mph (1061.8 km).

1948 Katherine Koontz Sanford (1948–) isolates a single mammalian cell *in vitro* and allows it to propagate to form identical descendants. Her clone of mouse fibroblasts was called L929, because it took 929 attempts before a successful propagation was achieved. The picture of this clone has often been reproduced. It was an important step in establishing pure cell lines for biomedical research.

1948 Marie Goeppert-Mayer (1906–1972), German-American physicist, suggests that the atomic nucleus consists of protons and neutrons arranged in shells. This makes it possible to explain why some nuclei are more stable than others, as well as why some elements are rich in isotopes. This concept of nuclear shells is advanced independently at the same time by the German physicist Johannes Hans David Jensen.

1948 Patrick Maynard Stuart Blackett (1897–1974), English physicist, wins the Nobel Prize for physics for his development of the Wilson cloud chamber method and his discoveries with it in the fields of nuclear physics and cosmic radiation.

1948 American zoologist and student of sexual behavior Alfred C. Kinsey (1894–1956) first publishes his *Sexual Behavior in the Human Male.*

1948 Arne Wilhelm Kaurin Tiselius (1902–1971), Swedish chemist, is awarded the Nobel Prize for chemistry for his research on electrophoresis and absorption analysis, especially for his discoveries concerning the complex nature of the serum proteins.

1948 Edward Lawrence Rickes, American biochemist, with N.G. Brink, F.R. Koniusky, T.R. Wood, and K. Folkers, first crystallize Vitamin B_{12}.

1948 George Gamow (1904–1968), Russian-American physicist, revises and extends the big bang theory of the creation of the universe. He also predicts the residual background radiation or echo of the primal explosion that Arno Allen Penzias (1933–) and Robert Woodrow Wilson (1936–) eventually discover in May 1964.

1948 Gerard Peter Kuiper (1905–1973), Dutch-American astronomer, detects carbon dioxide in the atmosphere of Mars and argues that the Martian polar caps are ice and not frozen carbon dioxide.

1948 Germanium crystals are used by the Bell Telephone Company in the United States to build the first transistors.

1948 The Hale reflector telescope is built on Mount Palomar, California. Named after American astronomer George Ellery Hale (1868–1938), who chose the site and began obtaining funds before he died, the Mount Palomar Observatory has a 200-inch (5.1 m) telescope and a 48-inch (1.2 m) camera.

1948 Paul Hermann Müller (1899–1965), Swiss chemist, is awarded the Nobel Prize for physiology or medicine for his discovery of the high efficiency of DDT as a contact poison against several arthropods.

1948 Philip S. Hench (1896–1965), American physician, and Edward C. Kendall (1886–1972), American biochemist, study the hormones of the adrenal gland and discover the anti-inflammatory effect of cortical hormones or cortisone for patients with rheumatoid arthritis.

1948 Seymour Morgan Farber, American physician, uses the first antimetabolite in cancer chemotherapy. He uses methotrexate (aminopterin) to treat leukemia.

1948 Thomas Gold (1920–2004), Austrian-British-American astronomer, introduces the concept of the steady state theory to astronomy. He suggests that the expansion of the universe is accounted for by the fact that as galaxies spread apart over billions of years, new matter is created in the empty space left behind and evolves into new galaxies. His theory is opposed by the "big bang" theory, which eventually wins out.

1948 U.S. Bureau of Mines and the Geological Survey cooperate in issuing the first overall appraisal of "the Nation's mineral wealth—its magnitude and degree of accuracy." This work is titled *Mineral Resources of the United States.*

1948 Walter Baade (1893–1960), German-American astronomer, discovers the asteroid Icarus. Its orbit carries it to within 18 million miles (29 million km) of the sun, making it the innermost known asteroid.

1948 William Wilson Morgan (1906–1994), American astronomer, collaborates with others and introduces the Yerkes system or MKK system of spectral classification of stars. This system adds a luminosity index to the older, one-dimensional system that used only a temperature index.

1948 Barbara McClintock (1902–1992) publishes her research on transposable regulatory elements in maize. McClintock had begun the work on a class of unstable mutant strains that led to this concept about six years before she published her results. These elements are sometimes referred to as "jumping genes." McClintock won the Nobel Prize in physiology or medicine in 1983.

1948 James V. Neel (1915–2000) reports evidence that the sickle-cell disease is inherited as a simple Mendelian autosomal recessive allele.

1948 The World Health Organization (WHO) is formed. The WHO subsequently becomes the principle international organization managing public health related issues on a global scale. Headquartered in Geneva, the WHO becomes, by 2002, an organization of more than 190 member countries. The organization contributes to international public health in areas including disease prevention and control, promotion of good health, addressing disease outbreaks, initiatives to eliminate diseases

(e.g., vaccination programs), and development of treatment and prevention standards.

1948 Cesare Mansueto Giulio Lattes (1924–2005), Brazilian physicist, and Eugene Gardner, American physicist, confirm the existence of heavy and light mesons and detect the first artificially-produced pion.

1948 A Naval Research Laboratory (NRL) experiment onboard a V2 rocket, which consisted of a photographic plate behind a beryllium filter that allowed only radiation of wavelengths shorter than 4 Angstroms (i.e., x rays) to pass through, detects an "unexpected" intensity level, which is interpreted as due to x rays from the sun.

1949 Hideki Yukawa (1907–1981), Japanese physicist, wins the Nobel Prize for physics for his prediction of the existence of mesons on the basis of theoretical work on nuclear forces.

1949 Choh Hao Li (1913–1987), Chinese-American chemist and endocrinologist, and Herbert McLean Evans (1882–1971), American anatomist and embryologist, first isolate follicle stimulating hormone (FSH). Produced by the pituitary gland, it stimulates the development of the graafian follicle in the female and promotes development of the testes in the male.

1949 Dorothy Crowfoot Hodgkin (1910–1994), English biochemist, is the first to use an electronic computer in direct application to a biochemical problem. She uses a computer to work out x ray data in her studies of the structure of penicillin.

1949 First gastric suction tube is invented by I.J. Wood.

1949 Gerard Peter Kuiper (1905–1973), Dutch-American astronomer, discovers a second satellite of Neptune and names it Nereid. The year before, he discovered the fifth and smallest satellite of Uranus, named Miranda.

1949 Giuseppe Moruzzi, Italian physiologist, and Horace Winchell Magoun, American neuroanatomist, demonstrate that signals from the brain stem keep the entire brain awake. This localizes the brain's "wakefulness center."

1949 Glenn Theodore Seaborg (1912–1999), American physicist, and colleagues prepare the transuranic element berkelium (number 97).

1949 Herbert Friedman (1916–2000), American astronomer, uses rockets to study x rays in outer space and demonstrates that the sun emits x rays

1949 J.G. Bolton of England and colleagues discover a galactic radio source that is a remnant of a supernova. They identify and map discrete radio sources coming from visible objects outside the solar system.

1949 John Presper Eckert, Jr. (1919–1995), American engineer, uses the newly-developed electronic computer to calculate the positions of the moon. This marks the entrance of the computer into astronomy.

1949 John Warren Graham, American geologist and geophysicist, points out the stability of magnetism in sedimentary rocks. His studies initiate modern research on the magnetic properties of rocks and the stability of these properties under various conditions.

1949 Lithium is used in the treatment of psychiatric disease.

1949 National Institute of Mental Health is established.

1949 R. Kurzrock and American pharmacologist Charles Christian Lieb (1880–1956) discover prostaglandins. This series of fatty acids is found in high amounts in semen but is also found in other organs and tissues. Considered hormones, they have a number of physiological roles and are still being studied.

1949 Ralph Belknap Baldwin (1912–), American astronomer, formulates his meteor impact theory explaining the condition of the lunar surface.

1949 Maurício Rocha e Silva and colleagues discover bradykinin in snake venom.

c. 1949 The role of mitochondria is finally revealed. These slender filaments, which are found in cells and can only be seen with a microscope, are its source of energy and are involved in protein synthesis and lipid metabolism.

1949 Walter R. Hess (1881–1973), Swiss physiologist, receives the Nobel Prize for his

experiments involving probes of deep-brain functions. Using microelectrodes to stimulate or destroy specific areas of the brain in experimental animals, he discovers the role played by certain parts of the brain in determining and coordinating the functions of internal organs.

1949 Walter Rudolf Hess (1881–1973), Swiss physiologist, is awarded the Nobel Prize for physiology or medicine for his discovery of the functional organization of the interbrain as a coordinator of the activities of the internal organs. António Caetano de Abreu Freire Moniz (1874–1955), Portuguese surgeon, is also awarded the Nobel Prize for physiology or medicine for his discovery of the therapeutic value of leucotomy in certain psychoses.

1949 William Francis Giauque (1895–1982), American chemist, is awarded the Nobel Prize for chemistry for his contributions in the field of chemical thermodynamics, particularly concerning the behavior of substances at extremely low temperatures.

1949 Frank Macfarlane Burnet (1899–1985) and his colleagues begin studies that lead to the immunological tolerance hypothesis and the clonal selection theory. Burnet receives the 1960 Nobel Prize in physiology or medicine for this research.

1949 EDSAC (Electronic Delay Storage Automatic Computer), the first practical stored-program computer, becomes operational. It is designed by English mathematician Maurice Vincent Wilkes (1913–), who establishes a library of short programs called subroutines that are stored on punched paper tapes.

1949 BINAC (Binary Automatic Computer), the first stored-program computer built in the United States, is tested and delivered to Northrop Aviation.

1949 U.S. researchers launch a captured German V-2 rocket from White Sands, New Mexico, and capture the sun's image in the far ultraviolet and soft x rays.

1949 The Soviet Union explodes an atomic bomb as a test, demonstrating its nuclear capability.

1950 Alfred Kastler (1902–1984), German-French physicist, develops a system of "optical pumping," in which atoms are excited by light or radio waves, allowing him to better study atomic structure. It leads eventually to the development of masers and lasers.

1950 Cecil Frank Powell (1903–1969), English physicist, wins the Nobel Prize for physics for his development of the photographic method of studying nuclear processes and his discoveries regarding mesons made with this method.

1950 Leo James Rainwater (1917–1986), American physicist, first suggests the correct idea that the nucleus of an atom is not spherical but rather spheroidal.

1950 A.C. Finlay and Gladys Lounsbury Hobby (1910–1993) of the United States discover the antibiotic drug Terramycin.

1950 Although the number of students graduated in geology is the highest to date, there is a continued demand for well-trained geologists. This is mainly due to the search for strategic and fissionable materials by private industry and government agencies.

1950 Dupont Company puts the first acrylic fiber on the market, calling it Orlon.

1950 Edward Calvin Kendall (1886–1972), American biochemist, Tadeus Reichstein (1897–1996), Polish-Swiss chemist, and Philip Showalter Hench (1896–1965), American physician, are awarded the Nobel Prize for physiology and medicine for their discoveries relating to the hormones of the adrenal cortex, their structure and biological effects.

1950 Erwin Chargaff (1905–2002), Austrian-American biochemist, establishes his rules about the basic chemistry of DNA. His findings contribute to greater understanding made during the next five years about the chemical structures of nucleic acids.

1950 Fred Lawrence Whipple (1906–2004), American astronomer, proposes his icy-nucleus model for the makeup of comets, describing them as a "dirty snowball." He suggests they are composed of water, ice, and dust, as well as carbon dioxide, carbon

monoxide, methane, and ammonia ice. As they approach the sun, they develop a swept-back tail as their ice vaporizes.

1950 Glenn Theodore Seaborg (1912–1999), American physicist, and colleagues artificially prepare element 98, californium.

1950 Jan Hendrik Oort (1900–1992), Dutch astronomer, offers his original theory on the origin of comets, saying that they compose a huge cloud of minor planets that envelope the sun. A few of these are hurled regularly into the solar system.

1950 Kenneth D. Orr of the U.S. Army leads a Cold Injury Research Team in Korea that obtains the first epidemiological data on frostbite. As a result of these studies, both military and civilian cold weather living is made safer and more functional.

1950 Lyman Spitzer, Jr. (1914–1997), American astronomer and physicist, invents the stellarator for containing very hot gases. His invention, which uses a twisting magnetic field that is wrapped around the hot plasma or gas, is a method for controlling fusion in experiments, and it grows out of his earlier research on fusion reactions in stars.

1950 Otto Paul Hermann Diels (1876–1954) and Kurt Adler (1902–1958), both German chemists, are awarded the Nobel Prize for chemistry for their discovery and development of the diene synthesis (a technique of atomic combination that can be put to use in the course of many different kinds of syntheses).

1950 Paul Karrer (1889–1971), Swiss chemist, and Hans Herloff Inhoffen achieve the first total synthesis of carotenoids.

1950 Douglas Bevis, British physician, demonstrates that amniocentesis can be used to test fetuses for Rh-factor incompatibility.

1950 Erwin Chargaff (1905–2002) demonstrates that the Tetranucleotide Theory was incorrect, and that DNA is more complex than the model that had been developed by Phoebus A. Levene (1869–1940). Chargaff proves that the nucleic acids are not monotonous polymers. Chargaff also discovers interesting regularities in the base composition of DNA; these findings are later known as "Chargaff's rules." Chargaff discovered a one-to-one ratio of adenine to thymine and guanine to cytosine in DNA samples from a variety of organisms.

1950 Ruth Sager's (1918–1997) work on the algae *Chlamydomonas* proves that cytoplasmic genes exist and that they can undergo mutation. She showed that such genes could be mapped on a "cytoplasmic chromosome." Confirmation was provided when other researches reported similar findings in yeast and *Neurospora,* and the DNA was located to cytoplasmic organelles.

1950 Robert Hungate develops a the roll-tube culture technique, which is the first technique that allows anaerobic bacteria to be grown in culture.

1950 The artificial sweetener cyclamate is first introduced to the market by Abbot Laboratories under the name Sucaryl. It does not have saccharin's aftertaste and becomes essential to the low-calorie soft drink industry.

1951 John Douglas Cockcroft (1897–1967), English physicist, and Ernest Thomas Sinton Walton (1903–1995), Irish physicist, win the Nobel Prize for physics for their pioneering work on the transmutation of atomic nuclei by artificially accelerated atomic particles.

1951 Alfred Charles Bernard Lovell (1913–), English astronomer, becomes the first professor of radio astronomy at Manchester University and begins work on a fully-steerable, 250-foot (76.2-m) "big dish" telescope at the Jodrell Bank Experimental Station. It is finished just in time to track Sputnik 1 on October 4, 1957.

1951 Armand John Eardley, American geologist, publishes his *Structural Geology of North America.* This large, comprehensive volume covers in detail the post-Proterozoic structural evolution of the North American continent.

1951 Charlotte Moore Sitterly (1898–1990), American astronomer, identifies the rare, unstable element technetium in the solar spectrum.

1951 Dirk Brouwer (1902–1966), Dutch-American astronomer, publishes the results of his study of the coordinates of the five outer planets for the years 1653 to 2060. This work represents the first use of a high-speed electronic computer to help solve a problem in astronomy.

1951 EDVAC (Electronic Discrete Variable Computer) is ready for operations. This long-awaited successor to ENIAC encounters many problems and has already seen the British EDSAC (Electronic Delay Storage Automatic Computer) become the first fully-functional stored-program computer.

1951 Edward Mills Purcell (1912–1997), American physicist, demonstrates that hydrogen atoms in space emit microwave radiation with a wavelength of 8.3 inches (21 cm). This confirms the theoretical prediction made by Hendrik van de Hulst in 1945.

1951 Edwin Mattison McMillan (1907–1991) and Glenn Theodore Seaborg (1912–1999), both American physicists, are awarded the Nobel Prize for chemistry for their discoveries in the chemistry of the transuranium elements.

1951 First successful oral contraceptive drug is introduced. Gregory Pincus (1903–1967), American biologist, discovers a synthetic hormone that renders a woman infertile without altering her capacity for sexual pleasure. It soon is marketed in pill form and effects a social revolution with its ability to divorce the sex act from the consequences of impregnation.

1951 First U.S. Army helicopter detachments, whose primary mission is casualty evacuation, become operational in Korea. In two years they will evacuate over 17,000 wounded.

1951 Gerard Peter Kuiper (1905–1973), Dutch-American astronomer, offers his theory arguing that the planets were formed by the gaseous condensation of what he calls "protoplanets." His work reorients astronomy back toward our own solar system.

1951 William Wilson Morgan (1906–1994), American astronomer, is the first to demonstrate the actual spiral structure of our galaxy.

1951 Hendrik Christoffel van de Hulst, Dutch astronomer, elaborates on the work of William Wilson Morgan (1951) and uses radio astronomy to confirm the spiral structure of our galaxy.

1951 IAS (Institute for Advanced Study) computer goes into limited operation. Developed by Hungarian-American mathematician John von Neumann (1903–1957) at Princeton University, it shatters computational speed records.

1951 International Business Machines Corporation (IBM) begins development of its IBM 701. Programmed to play checkers, this is a computer that can "learn" from its experience.

1951 Jacques-Jean Lhermitte (1877–1959) of France publishes *Le Cerveau et La Pensée*, which stresses the regulation of mental life by the hormones.

1951 Joseph E. Smadel (1907–1963), Kenneth Goodner, Fred R. McCrumb, Jr., and Theodore E. Woodward (1914–2005), American physicians, are the first to demonstrate that broad spectrum antibiotics can cure septicemic and pneumonic types of human plague.

1951 Max Theiler (1899–1972), South African-American microbiologist, is awarded the Nobel Prize for physiology or medicine for his discoveries concerning yellow fever and how to combat it.

1951 Robert Burns Woodward (1917–1979), American chemist, and colleagues first synthesize such steroids as cholesterol and cortisone.

1951 Rudolph Leo B. Minkowski (1895–1976), German-American astronomer, collaborates with countryman Walter Baade (1893–1960) and makes the first optical identification of a discrete radio source, Cygnus A. He also locates the remnants of a long-exploded supernova.

1951 Technique of electrode implantation is first developed and leads to the discovery of the brain's "pleasure centers."

1951 The effectiveness of fluoride in the prevention of tooth decay is discovered.

1951 With the electrical recording from single cells achieved, the controversy over the

nature of transmission at the nerve junction is resolved in favor of the "soup" (chemical) theory rather than the "spark" (electrical) theory.

1951 A machine based in part on the plans of Alan Turing (1912–1954) is completed at the University of Manchester by Harry Huskey (1916–). Called Pilot ACE (Automatic Computing Engine), the machine is asserted by many to be the world's first programmable digital computer.

1951 Esther M. Lederberg (1922–2006) discovers a lysogenic strain of *Escherichia coli* K12 and isolates a new bacteriophage, which is called lambda.

1952 Donald Arthur Glaser (1926–), American physicist, constructs the first bubble chamber. This new method uses liquid hydrogen and proves far more sensitive than cloud chambers.

1952 Edward Teller (1908–2003), Hungarian-American physicist, develops a device that makes the development of the hydrogen-fusion bomb (H-bomb) practical.

1952 Felix Bloch (1905–1983), Swiss-American physicist, and Edward Mills Purcell (1912–1997), American physicist, win the Nobel Prize for physics for their development of new methods for nuclear magnetic precision measurements and for discoveries in connection with them.

1952 Alan L. Hodgkin (1914–1998) and Andrew F. Huxley (1917–), both English physiologists, first work out the mechanism of nerve-impulse transmission, showing that a "sodium pump" system works to carry impulses.

1952 Alfred Day Hershey (1908–1997), American virologist, and Martha Chase (1927–2003), American geneticist, experiment with phage and viruses and finally prove that DNA is the hereditary material. Phage or bacteriophage is a type of virus that infects bacteria cells. Because of its useful properties and simple nature, it becomes the fruit fly of the molecular biologists.

1952 Archer John Porter Martin (1910–2002) and Richard Laurence Millington Synge (1914–1994), both English chemists, are awarded the Nobel Prize for chemistry for their invention of partition chromatography. Martin protests that he should share his honor with his colleague, L.T. James, rather than with Synge, and he gives James half his prize money.

1952 Archer John Porter Martin, English biochemist, and L.T. James perfect gas chromatography or vapor-phase chromatography. It is a variant of partition chromatography and permits the separation and identification of mixture components.

1952 Harold Delos Babcock (1882–1968) and his son, Horace Welcome Babcock, both American astronomers, first detect localized magnetic fields on the surface of the sun using the solar magnetograph they invented the year before.

1952 Hermann Bondi (1919–2005), Austrian-British mathematician, publishes his *Cosmology*, in which he discusses and supports the steady-state theory of the origin of the universe. He offers mathematical underpinnings to the steady-state model.

1952 J. Delay of France discovers the antipsychotic action of Largactyl (chloropromazine). This breakthrough opens up the new field of psychotherapeutic drugs.

1952 Maurice Hugh Frederick Wilkins (1916–2004), New Zealand biophysicist, and Rosalind Elsie Franklin (1920–1958), British physicist, take x-ray diffraction pictures of DNA. This information greatly helps James Watson and Francis Crick.

1952 Modern studies of "superclusters" begin as discoveries of "clusters of clusters" of galaxies are made. These are found to be a remarkable concentration of bright galaxies in one part of the sky.

1952 Paul M. Zoll (1911–1999), American physician, first develops the technique of external heart stimulation by electric shock in cases of cardiac arrest. He also introduces the first practical cardiac pacemaker. In 1956 he introduces the external defibrillator.

1952 Paul Willard Merrill (1887–1961), American astronomer, identifies the rare, unstable element technetium in Type S stars. Since this element has a short

half-life, it implies that these super-giant stars are relatively young.

1952 Richard Laurence Millington Synge (1914–1994), English biochemist, and Archer John Porter Martin (1910–2002), English chemical engineer, develop partition or separative chromatography.

1952 Selman Abraham Waksman (1888–1973), Russian-American microbiologist, is awarded the Nobel Prize for physiology or medicine for his discovery of streptomycin, the first antibiotic effective against tuberculosis.

1952 Walter Baade (1893–1960), German-American astronomer, discovers that the distance of the Andromeda galaxy is over 2 million light-years away and not the 800,000 that Edwin Hubble had estimated. This fact increases the entire universe by twenty in volume and makes the age of the universe at least five or six billion years old.

1952 William G. Gochenour of the United States demonstrates that pretibial fever (also called Fort Bragg Fever) is not caused by a virus but rather is an infection caused by a microorganism called *Leptospira.*

1952 Renato Dulbecco (1914–) develops a practical method for studying animal viruses in cell cultures. His plaque method was comparable to that used in studies of bacterial viruses, and it was important in genetic studies of viruses. These methods were described in his paper "Production of Plaques in Monolayer Tissue Cultures by Single Particles of an Animal Virus."

1952 Rosalind Franklin (1920–1958) gives a seminar on her x-ray crystallography studies of two forms of DNA. Her colleague, Maurice Hugh Frederick Wilkins (1916–2004), gives information about her work to James Watson.

1952 William Hayes (1918–1994) isolates a strain of *E. coli* that produces recombinants thousands of times more frequently than previously observed. The new strain of K12 was named Hfr Hayes, to signify high-frequency recombination.

1952 James T. Park and Jack L. Strominger demonstrate that penicillin blocks the synthesis of the peptidoglycan of bacteria. This represents the first demonstration of the action of a natural antibiotic.

1952 Joshua Lederberg (1925–2008) coins the term plasmid to describe genetic material that is capable of replicating but which is not part of the chromosome.

1952 Karl Maramorosch demonstrates that some viruses could multiply in both plants and in insects. This work leads to new questions about the origins of viruses.

1952 Joshua Lederberg (1925–2008) and Esther Zimmer Lederberg (1922–2006) develop the replica plating method that allows for the rapid screening of large numbers of genetic markers. They use the technique to demonstrate that resistance to antibacterial agents such as antibiotics and viruses is not induced by the presence of the antibacterial agent.

1952 Douglas Bevis, English physician, publishes an article describing his use of amniocentesis in Rh-factor cases. This process uses a needle to obtain samples of amniotic fluid (in which the fetus floats) from a mother's womb. This is the first use of amniocentesis for a fetal diagnosis.

1952 First mechanical heart pump is used successfully on a human being undergoing heart surgery. Designed by American surgeon Forest D. Dodrill, with help from General Motors engineers, the portable electric pump performs the heart's functions while it is undergoing surgical repair.

1952 Charles Hufnagel (1916–1989) of the United States inserts the first artificial heart valve.

1952 A UNIVAC I computer is used to predict the election of Dwight David Eisenhower (1890–1969) as President of the United States based on early returns.

1952 First thermonuclear device is exploded successfully by the United States at the Eniwetok Atoll in the South Pacific. This hydrogen-fusion bomb (H bomb) is the first such bomb to work by nuclear fusion and is enormously more powerful than the atomic bomb exploded over Hiroshima, Japan, on August 6, 1945.

1953 Fritz Zernicke (1888–1966), Dutch physicist, wins the Nobel Prize for physics for his demonstration of the phase contrast method, especially for his invention of the phase contrast microscope.

1953 Murray Gell-Mann (1929–), American physicist, suggests that basic particles contain an intrinsic property known as "strangeness," which can explain a number of new observations being made about them. A similar concept is developed independently by the Japanese physicist Kazuhiko Nishijima.

1953 Cryosurgery begins to be developed. This surgical technique removes targeted tissue by freezing and thus destroying it. Special instruments are used with freezing tips that kill unwanted tissue. It is relatively bloodless, because reduced temperatures cause constriction of blood vessels.

1953 ERA 1103 computer, built by Engineering Research Associates, is the first commercial computer to use interrupts (which permits it to respond quickly to exceptional events) and the first commercial computer to have a core memory.

1953 First hydrometallurgical plant to use high pressure and temperature for the processing of nickel, copper, and cobalt is built in Canada.

1953 Francis Harry Compton Crick (1916–2004), English biochemist, and James Dewey Watson (1928–), American biochemist, work out the double-helix or double spiral DNA model. This model explains how it is able to transmit heredity in living organisms.

1953 Giulio Natta (1903–1979), Italian chemist, borrows Ziegler's (1953–) idea of a new catalyst for polymers and develops the first "isotactic" polymers, which allow their production at will.

1953 Hans Adolf Krebs (1900–1981), German-British chemist, is awarded the Nobel Prize for physiology or medicine for his citrus acid cycle work in the 1940s. Krebs determines the nature of what is a regenerating series of chemical changes that occur during carbohydrate metabolism. Called the "Krebs cycle," this process is the major energy producer in living organisms. Fritz Albert Lipmann (1899–1986), German-American biochemist, is also awarded the Nobel Prize for physiology or medicine for his discovery of co-enzyme A and its importance for intermediary metabolism.

1953 Henry Bernard Davis Kettlewell (1907–1979), English physician and entomologist, publishes his work on industrial melanism in moths, demonstrating the first case of evolution that can be witnessed as it occurs.

1953 Hermann Staudinger (1881–1965), German chemist, is awarded the Nobel Prize for chemistry for his discoveries in the field of macromolecular chemistry.

1953 Iosif Samuilovich Shklovskii (1916–1985), Russian astrophysicist, first proposes his synchrotron-emission theory. He suggests that the high-energy particles emitted by the Crab Nebula also emit radio waves.

1953 J. Halcombe Laning and Niel Zierler of the United States invent the first truly practical compilers and high-level languages for Project Whirlwind. Their system uses ordinary words such as "stop" and "print" as well as equations. It requires so much machine time to translate however, that it is rarely used.

1953 James Olds (1922–1976), American researcher, discovers a pleasure center in the brain.

1953 John Backus (1924–2007), American programmer, invents Speedcoding, an early high-level assembly language. This will lead directly to his development of FORTRAN (FORmula TRANslation) software.

1953 Joshua Lederberg (1905–2008) and Norton David Zinder (1928–), both American geneticists, discover transduction in Salmonella.

1953 Karl Ziegler (1898–1973), German chemist, discovers a resin catalyst for the production of polyethylene. This produces a new, tougher product that has a much higher melting point than its old counterpart.

1953 Magnetic core memory makes its first appearance and significantly improves the

performance of the Whirlwind computer. Developed by American electrical engineer Jay Wright Forrester (1918–), it will prove to be the first real system to offer a basis for a large-scale memory at reasonable cost.

1953 Michael Ellis DeBakey (1908–), American surgeon, performs the first successful carotid endarterectomy.

1953 Peter Brian Medawar (1915–1987), English biologist, working with Frank Macfarlane Burnet (1899–1985), Australian physician, shows that tolerance to skin grafts can be conferred by inoculating a newborn animal or embryo with antibodies from a future donor.

1953 Sergei Alekseevich Lebedev (1902–1974), Russian electrical engineer, builds one of the first Soviet computers; it is called the BESM1.

1953 William Maurice Ewing (1906–1974), American geologist, proposes the existence of a great rift (split) that runs down the middle of the Mid-Atlantic Ridge.

1953 Scientists estimate that there are 100 computers in the world.

1953 Jonas Edward Salk (1914–1995) begins testing a polio vaccine comprised of a mixture of killed viruses.

1953 First successful open-heart operation using a heart-lung machine is conducted by American surgeon John Heysham Gibbon, Jr. (1903–1973).

1953 Charles Hard Townes (1915–), American physicist, designs the first working model of a maser (Microwave Amplification by Stimulated Emission of Radiation). This new devices produces an intense beam of radiation of a precise wavelength in the microwave part of the spectrum and finds use in atomic clocks and receivers in radio telescopes. It also leads to the development of the laser, called the optical maser since it amplifies light rather than microwave radiation.

1954 Luis Walter Alvarez (1911–1988), American physicist, develops the liquid hydrogen bubble chamber, in which subatomic particles and their reactions are detected.

1954 Max Born (1882–1970), German-English physicist, and Walther Wilhelm Georg Bothe (1891–1957), German physicist, win the Nobel Prize for physics. Born wins it for his fundamental research in quantum mechanics, especially for his statistical interpretation of the wave function. Bothe wins it for the coincidence method and the discoveries made with it.

1954 First clinical trials of oral contraceptives are conducted.

1954 Frank Milan Berger, Czech-American physician and pharmacologist, first uses meprobamate to treat anxiety.

1954 Frederick Sanger (1918–), English biochemist, determines the sequence of amino acids in insulin. This difficult achievement is a real breakthrough in protein chemistry and leads to knowledge of the exact structure of even more complicated compounds.

1954 Glenn Theodore Seaborg (1912–1999), American physicist, and colleagues artificially prepare einsteinium (element 99) and fermium (element 100).

1954 John Franklin Enders (1897–1985), American micrologist, and Thomas Peebles, American pediatrician, develop the first vaccine for measles. A truly practical and successful vaccine requires more time.

1954 John Franklin Enders (1897–1985), Thomas Huckle Weller (1915–), and Frederick Chapman Robbins (1916–2003), all American microbiologists, are awarded the Nobel Prize for physiology or medicine for their discovery of the ability of poliomyelitis viruses to grow in cultures of various types of tissue.

1954 Jonas Edward Salk (1914–1995), American virologist, produces the first successful anti-poliomyelitis vaccine, which prevents paralytic polio. It is soon (1955) followed by the Polish-American virologist Albert Bruce Sabin's (1906–1993) development of the first oral vaccine.

1954 Linus Carl Pauling (1901–1994), American chemist, is awarded the Nobel Prize for chemistry for his research into the nature of the chemical bond and its application to the elucidation of the structure of complex substances.

1954 National Geographic Society and the Mt. Palomar Observatory join in publishing the *National Geographic-Mt. Palomar Sky Atlas.*

1954 Philip Hauge Abelson (1913–2004), American physical chemist, reports his discovery of amino acids in fossils and fatty acids in rocks that were more than one billion years old.

1954 Robert Burns Woodward (1917–1979), American chemist, first synthesizes strychnine.

1954 Vincent Du Vigneaud (1901–1978), American biochemist, studies the hormones produced by the pituitary gland and produces the first protein hormone ever synthesized. This leads the way to similar understanding of more complicated proteins.

1954 Seymour Benzer (1921–2007) works out the fine structure of the rII region of the bacteriophage T4 of *E. coli,* and coins the terms cistron, recon, and muton.

1954 Joseph Edward Murray (1919–), American surgeon, conducts the first successful organ transplant as he transfers the kidney of one twin to another.

1955 Emilio Gino Segrè (1905–1989), Italian-American physicist, and American physicist Owen Chamberlain (1920–2006) are the first to detect antiprotons by bombarding copper atoms with protons.

1955 Frederick Reines (1918–1998) and Clyde Lorrain Cowan (1919–1974), American physicists, detect and observe neutrinos for the first time.

1955 Willis Eugene Lamb Jr. (1913–2008) and Polykarp Kusch (1911–1993), American physicists, win the Nobel Prize for physics. Lamb wins it for his discoveries concerning the fine structure of the hydrogen spectrum, and Kusch wins it for his precision determination of the magnetic moment of the electron.

1955 Alexander Mikhailovich Prokhorov (1916–2002) and Nikolai Gennadievich Basov (1922–2001), both Russian physicists working at the same time as Charles Townes, develop the theoretical basis of the maser.

1955 Axel Hugo Theodor Theorell (1903–1982), Swedish biochemist, is awarded the Nobel Prize for physiology or medicine for his discoveries concerning the nature and mode of action of oxidation enzymes.

1955 Federico E. Ahlfeld publishes *Los Yacimientos Minerales de Bolivia*, which is the first all-inclusive publication on the mineral deposits of Bolivia. It includes maps, cross sections, descriptions of mining districts and individual deposits, and production of export data.

1955 First glass with a regular crystalline molecular pattern is discovered.

1955 Joel E. Warren, American physician, begins work on the development of a "jet injection" device, which utilizes compressed air for immunization. It will eventually become a jet injector "gun," which reduces the cost of mass immunizations and permits a large number of people to be immunized in a short time.

1955 Kenneth Linn Franklin (1923–2007), American astronomer, discovers that the planet Jupiter is a source of radio waves. It is later learned that the source is the planet's immense magnetic field.

1955 Synthetic diamonds are produced in the General Electric Laboratories.

1955 The soft ear insert for protection against deafening noise is developed by the U.S. Army Audiology and Speech Center. This is a major improvement over the old, hard acrylic ear insert.

1955 Victor Ambartzumian (1908–1996), Armenian astronomer, suggests that the radio sources earlier identified by Walter Baade and Rudolph Minkowski are not the result of colliding galaxies but rather evidence of vast explosions within the core of galaxies. His analogy to a supernova on a galactic scale has become firmly established.

1955 Vincent Du Vigneaud (1901–1978), American biochemist, is awarded the Nobel Prize for chemistry for his work on biochemically important sulfur compounds, especially for the first synthesis of a polypeptide hormone.

1955 Fred L. Schaffer and Carlton E. Schwerdt report on their successful crystallization of the polio virus. Their achievement is the first successful crystallization of an animal virus.

1955 Heinz Fraenkel-Conrat (1910–1999) and Robley C. Williams (1908–1995) prove that tobacco mosaic virus can be reconstituted from its nucleic acid and protein subunits. The reconstituted particles exhibit normal morphology and infectivity.

1956 Nicolaas Bloembergen (1920–), Dutch-American physicist, designs the first continuous maser. This is a solid-state maser that can steadily produce energy.

1956 William Bradford Shockley (1910–1989), English-American physicist, John Bardeen (1908–1992), American physicist, and Walter Houser Brattain (1902–1987), American physicist, win the Nobel Prize for physics for their researches on semiconductors and their discovery of the transistor effect.

1956 André Frédéric Cournand (1895–1988), French-American physiologist, Werner Forssmann (1904–1979), German surgeon, and Dickinson Woodruff Richards (1895–1973), are awarded the Nobel Prize for physiology or medicine for their discoveries concerning heart catheterization and pathological changes in the circulatory system.

1956 Bruce Charles Heezen (1924–1977), American oceanographer and geologist, and William Maurice Ewing (1906–1974), American geographer, discover the Mid-Oceanic Ridge. This is a gigantic, undersea mountain chain that encircles Earth and runs continuously for 40,000 miles (64,373.8 km).

1956 Choh Hao Li (1913–1987), Chinese-American biochemist, isolates human growth hormone and shows that it is far more complicated and quite different from other species tested.

1956 Cyril Norman Hinshelwood (1897–1967), English physical chemist, and Nikolay Nikolayevich Semenov (1896–1986), Russian physical chemist, are awarded the Nobel Prize for chemistry for their researches into the mechanism of chemical reactions.

1956 Herbert Edwin Hawkes, Jr., American geologist, makes the first major geochemical sampling of stream sediments for metal prospecting.

1956 Herbert Friedman (1916–2000), American astronomer, demonstrates that solar flares are one source of the sun's emission of x rays. Two years later he shows that sun's corona also produces x rays.

1956 International Business Machines Corporation (IBM) begins the era of magnetic-disk storage with its RAMAC computer, which has the first disk drive, called the IBM 305 disk file. It can hold 5 million bytes of data.

1956 Joe Hin Tjio (1916–2001), Indonesian-American biologist, and Johann Albert Levan, Swiss chromosome cytologist, show that the human species does not have 48 chromosomes as believed since the early 1920s, but rather has 46 chromosomes.

1956 John McCarthy (1929–), American mathematician and computer scientist, coins the term "artificial intelligence."

1956 Niels Kai Jerne (1911–1994), Danish physician, proposes the clonal selection theory of antibody selection to explain how white blood cells are able to produce a large range of antibodies.

1956 Robert Burns Woodward (1917–1979), American chemist, synthesizes reserpine, which becomes the first of the tranquilizing drugs.

1956 Walter Hermann Bucher (1888–1965), American geologist, offers his theory of the origin and geographic pattern of mountain chains and describes the mountain building cycle.

1956 William Joscelyn Arkell (1904–1958), English paleontologist, publishes his *Jurassic Geology of the World*, which offers for the first time a comprehensive stratigraphical picture of this particular age. It also stimulates further development of a stratigraphical classification applicable to all geological systems and periods.

1956 Arthur Kornberg (1918–2007) demonstrates the existence of DNA polymerase in *E. coli.*

1956 Mary F. Lyon (1925–) proposes that one of the X chromosomes of normal females is inactivated. This concept became known as the Lyon hypothesis and helps explain some confusing aspects of sex-linked diseases. Females are usually "carriers" of genetic diseases on the X chromosome, because the normal gene on the other chromosome protects them, but some X-linked disorders are partially expressed in female carriers. Based on studies of mouse coat color genes, Lyon proposed that one X chromosome is randomly inactivated in the cells of female embryos.

1956 Vernon M. Ingram (1924–2006) reports that normal and sickle cell hemoglobin differ by a single amino acid substitution.

1956 Alfred Gierer and Gerhard Schramm demonstrate that naked RNA from tobacco mosaic virus is infectious. Subsequently, infectious RNA preparations are obtained for certain animal viruses.

1956 Tsung-Dao Lee (1926–) and Chen Ning Yang (1922–), both Chinese-American physicists, conclude that the conservation of parity rule does not hold for weak interactions. They then work to design an experiment that will prove this conclusively.

1957 Chen Ning Yang (1922–) and Tsung-Dao Lee (1926–), Chinese-American physicists, win the Nobel Prize for physics for their penetrating investigation of the so-called parity laws, which lead to important discoveries regarding elementary particles.

1957 Leo Esaki (1925–), Japanese physicist, works in solid-state physics and discovers the "tunnel effect." He finds that are times when resistance decreases with current intensity instead of increasing as was expected. This is caused by the barrier-crossing ability of electrons.

1957 Alexander Robertus Todd (1907–1997), Scottish chemist, is awarded the Nobel Prize for chemistry for his work on nucleotides and nucleotide co-enzymes.

1957 Alick Isaacs (1921–1967), Scottish virologist, demonstrates that antibodies act only against bacteria. This means that antibodies are not one of the body's natural forms of defense against viruses. This knowledge leads eventually to the discovery of interferon this same year by Isaacs and his colleague, Jean Lindenmann of Switzerland. They find that the generation of a small amount of protein is the body's first line of defense against a virus.

1957 Alick Isaacs (1921–1967), Scottish virologist, and Jean Lindenmann of Switzerland discover interferon. They find that the body naturally produces a protein that is its first line of defense against invading viruses.

1957 Arthur Kornberg (1918–2007), American biochemist, first forms synthetic molecules of DNA, although they are not biologically active.

1957 Daniel Bovet (1907–1992), Swiss-French-Italian pharmacologist, is awarded the Nobel Prize for physiology or medicine for his discoveries relating to synthetic compounds that inhibit the action of certain body substances, especially their action on the vascular system and the skeletal muscles.

1957 First industrially-produced synthetic diamonds (by the General Electric Company) are put on the market.

1957 Jodrell Bank Experimental Station becomes operational. Also called the Nuffield Radio Astronomy Laboratories, this English facility has a fully steerable radio telescope with a 250-foot (76.2-m) diameter reflector.

1957 Martin Ryle (1918–1984), English astronomer, suggests that the changes in the brightness of Seyfert galaxies are caused by the ejection of chunks of matter that can travel at nearly the speed of light.

1957 Maurice Solomon Raben, American physician, first develops a method for the extraction of human GH (growth hormone) from the pituitaries of cadavers.

1957 Noam Chomsky (1928–), American psycholinguist, first claims in his book *Syntactic Structure* that the human brain is born programmed for learning language.

He offers the revolutionary idea that all languages share a universal grammar that lies below the surface of all the different grammars.

1957 The structure of viruses is determined. Through the work of Heinz Fraenkel-Conrat (1910–1999), German-American biochemist, viruses are seen as consisting of a hollow protein shell with a nucleic acid molecule within.

1957 Vernon Benjamin Mountcastle (1918–), American neurophysiologist, demonstrates that the neurons or nerve cells in the brain's cortex are arranged in a million columns.

1957 François Jacob (1920–) and Élie L. Wollman demonstrate that the single linkage group of *Escherichia coli* is circular and suggest that the different linkage groups found in different Hfr strains result from the insertion at different points of a factor in the circular linkage group that determines the rupture of the circle.

1957 The World Health Organization advances the oral polio vaccine developed by Albert Sabin as a safer alternative to the Jonas Salk vaccine.

1957 Chien-Shiung Wu (1912–1997), Chinese physicist, announces that her experiments demonstrate that the principle of parity is flawed. She bases her studies on the theoretical work of two Chinese-American physicists, Chen Ning Yang (1922–) and Tsung-Dao Lee (1926–). This principle states that, on a nuclear level, an object and its mirror image will behave the same way. Disproving this principle eventually allows new and more correct views about neutrinos to emerge.

1957 International Geophysical Year, officially designated as the period between July 1957 and December 1958, begins. This international agreement views Earth globally and stimulates and coordinates the research programs of the 70 participating nations in a systematic study of Earth and its surrounding space.

1958 Pavel Alekseyvic Cerenkov (1904–1990), Ilya Michailovic Frank (1908–1990), and Igor Yevgenyevich Tamm (1895–1971), Russian physicists, win the Nobel Prize for physics for their discovery and interpretation of the Cerenkov effect (the principle of light emission by electrically-charged particles moving faster than the speed of light in a medium).

1958 Aaron Bunsen Lerner, American physician, and his group first isolate the pineal hormone melatonin, a methoxy derivative of serotonin. They call it melatonin because it is related to melanin and serotonin.

1958 American geologists Leonard Frederick Herzog (1925–1995), William Hamet Pinson, Jr., and Randal Cornier publish an article in which they offer a method of determining the age of a sediment by using the ratio of rubidium to strontium. This dating method can be applied to sediments rather than igneous rocks or ore deposits and is considered to have wide application.

1958 Denis Burkitt (1911–1993), Irish physician, publishes his first account of what becomes known as "Burkitt's lymphoma." This virus-caused disease is prevalent in Southeast Asia.

1958 Element 101 is artificially produced by Glenn Theodore Seaborg (1912–1999), American physicist, and colleagues and is named mendelevium after the originator of the periodic table. They also produce nobelium (element 102) this year.

1958 First international textbook on surgery, *Emergency War Surgery*, is published by NATO (North Atlantic Treaty Organization).

1958 First use is made of closed-chest cardiac massage combined with mouth-to-mouth respiration for cardiac resuscitation.

1958 Francis Harry Compton Crick (1916–2004), English biochemist, predicts the discovery of transfer DNA.

1958 Fredrick Sanger (1918–), English biochemist, is awarded the Nobel Prize for chemistry for his work on the structure of proteins, especially that of insulin.

1958 George Wells Beadle (1903–1989), American geneticist, and Edward Lawrie Tatum (1909–1975), American biochemist, are awarded the Nobel Prize for physiology

or medicine for their discovery that genes act by regulating definite chemical events. Joshua Lederberg (1925–2008), American geneticist, also is awarded the Nobel Prize for physiology or medicine for his discoveries concerning genetic recombination and the organization of the genetic material of bacteria.

1958 Margaret Shiner invents the intestinal biopsy tube.

1958 Nikolai Alexandrovich Kozyrev (1908–1983), Russian astronomer, observes the formation of a cloud or mist in the crater Alphonsus on the moon and takes a spectrum reading that indicates that it might be the result of something like volcanic activity. This is the first observation of the moon since the time of Galileo that even hints at the notion that it is anything but a cold, dead place.

1958 Rudolf Ludwig Mossbauer (1929–), German physicist, announces what becomes known as the Mossbauer effect. While studying the recoil that occurs when an atomic nucleus emits a gamma ray, he discovers the phenomenon of recoilless nuclear resonance absorption. This useful tool for precision measurement allows scientists to test and verify in 1960 Einstein's general theory of relativity.

1958 The human chemical called Dopamine is identified as a neurotransmitter.

1958 James Alfred Van Allen (1914–2006), American physicist, designs a special cosmic ray counter that is launched aboard the U.S. satellite *Explorer 4*. He correctly assumes that the counters launched previously, which unaccountably stopped working, had passed through radiation much too high for their instruments. His device not only proves him correct, but discovers what comes to be called the "Van Allen Belt." This is a region of very high radiation levels that widely encircle Earth around the equator and curve in dramatically near the poles.

1958 The National Aeronautics and Space Administration (NASA) begins its first official day as the new U.S. agency responsible for aeronautical and space research. All existing National Advisory Committee for Aeronautics (NACA) facilities, personnel, policies, and advisory committees are transferred to NASA.

1958 The era of active satellite communications begins as the United States launches an Air Force Atlas booster to place into orbit a communications relay satellite, PROJECT SCORE (Signal Communications by Orbiting Relay Equipment) or the "talking atlas," into Earth orbit. The 8,750-pound (3,969 kg) relay satellite beams a Christmas message from U.S. President Dwight David Eisenhower (1890–1969) on December 19, 1958. This is the first voice broadcast from space.

1959 Emilio Gino Segrè (1905–1989), Italian-American physicist, and Owen Chamberlain (1920–2006), American physicist, win the Nobel Prize for physics for their discovery of the antiproton.

1959 Jaroslav Heyrovsk (1890–1967), Czech physical chemist, is awarded the Nobel Prize for chemistry for his discovery and development of the polarographic methods of analysis.

1959 Albert Bruce Sabin (1906–1993), Polish-American virologist, announces successful results from testing live attenuated polio vaccine. His vaccine is preferred over the Jonas Salk vaccine, since it can be administered orally and offers protection with a single dose.

1959 Arthur Kornberg (1918–2007), American biochemist, and Severo Ochoa (1905–1993), Spanish-American biochemist, are awarded the Nobel Prize for their discovery of enzymes that produce artificial DNA and RNA (synthesize *in vitro* polymers of ribonucleotides and deoxyribonucleotides).

1959 Eugene Newman Parker (1927–), American physicist, predicts the existence of what becomes known as the "solar wind." Studying the movement of high-energy particles in space, he predicts that charged particles will be emitted in all directions by the sun and will follow the lines of force of its magnetic field. This phenomenon

is verified by the *Mariner 2* Venus probe launched by the United States in 1962.

1959 First major description of COBOL (Common Business Oriented Language) is completed. It excels at the most common types of data processing for business and becomes available the following year. This language becomes the most widely used programming language for commercial applications in the 1970s.

1959 First tanker for the transport of liquid methane, the *Methane Pioneer*, makes its initial transatlantic crossing from Louisiana to England.

1959 Joseph Polonski of Russia describes the role of desoxyribonucleic acid (DNA) in the internal functioning of cells.

1959 Jérôme Jean Louis Marie Lejeune (1927–1994), French pediatrician, and colleagues Marthe Gautier and Raymond A. Turpin discover the first disease characterized by chromosome aberration involving trisomy of a small telocentric chromosome. That is, they discover that patients with Down's syndrome (also called Mongoloids) have 47 chromosomes instead of the usual 46. The extra is a third copy of chromosome 21.

1959 Martin Ryle (1918–1984), English astronomer, completes the *Third Cambridge Catalogue*, which lists the positions and strengths of over 500 radio sources in the sky. It becomes the definitive catalog used by all radio astronomers. He also develops systems to increase the sharpness of radio telescopes.

1959 Peter Karlson, German chemist, and Martin Luscher, Swiss zoologist, introduce the term "pheromone" to indicate hormones produced by an organism that act upon other individuals of the same species.

1959 Severo Ochoa (1905–1993), Spanish-American biochemist, and Arthur Kornberg (1918–2007), American biochemist, are awarded the Nobel Prize for physiology or medicine for their discovery of the mechanisms in the biological synthesis of ribonucleic acid and deoxyribonucleic acid.

1959 The first commercial Xerox copier is introduced.

1959 William Bennett Kouwenhoven (1886–1975), American electrical engineer, introduces the technique of closed-chest cardiac massage to revive victims of cardiac arrest.

1959 Robert Louis Sinsheimer (1920–) reports that bacteriophage +X174, which infects *E. coli,* contains a single-stranded DNA molecule, rather than the expected double stranded DNA. This provides the first example of a single-stranded DNA genome.

1959 English biochemist Rodney Porter (1917–1985) begins studies that lead to the discovery of the structure of antibodies. Porter receives the 1972 Nobel Prize in physiology or medicine for this research.

1959 Sydney Brenner (1927–) and Robert W. Horne publish a paper titled "A Negative Staining Method for High Resolution Electron Microscopy of Viruses." The two researchers develop a method for studying the architecture of viruses at the molecular level using the electron microscope.

1959 The American Geological Institute begins publication of the *International Geology Review.* This monthly journal will contain reviews of important trends in foreign geologic research and translations of outstanding reports in languages other than English.

1959 The United States sends *Pioneer 4* to the moon, successfully making the first U.S. lunar flyby.

1959 NASA unveils the first (Mercury) astronaut corps in a press conference in Washington, D.C. The seven men are: from the Marine Corps, Lt. Col. John H. Glenn, Jr. (1921–); from the Navy, Lt. Cdr. Walter M. Schirra, Jr. (1923–), Lt. Cdr. Alan B. Shepard, Jr. (1923–1998), and Lt. M. Scott Carpenter (1925–); and from the Air Force, Capt. L. Gordon Cooper (1927–), Capt. Virgil I. "Gus" Grissom (1926–1967), and Capt. Donald K. Slayton (1924–1993).

1959 The United States launches and recovers two monkeys, Able and Baker, after launch in a Jupiter missile nosecone during a suborbital flight. The flight is successful, testing the capability to launch from Cape

Canaveral, Florida, and to recover spacecraft in the Atlantic Ocean. Able died several days later from a reaction to the anesthesia given for the flight. Baker survived until 1984.

1959 The first man-made object to impact the moon is the Soviet Union's *Lunik 2*. The 858-pound (389 kg) capsule is sterilized so as not to contaminate the moon.

1959 The first nuclear-powered surface ship, the Soviet ice-breaker *Lenin*, makes its maiden voyage. Designed to work in ice up to 6 feet (1.8 m) thick, it carries enough fuel to cruise for a year.

1959 The first powered flight of the U.S. research aircraft *X-15* is made. It is released from its *B-52* mother ship and flown by American pilot A. Scott Crossfield (1921–2006) at Mach 2.3 (over twice the speed of sound). It later passes Mach 6.

1959 NASA launches the *Explorer 7* satellite, carrying ion chambers provided by the Naval Research Laboratory that were intended to detect (solar) x rays (and Lyman-alpha), and thus, was arguably the second satellite x-ray observatory. Unfortunately, like Vanguard 3, the Van Allen Belt radiation swamped the detectors most of the time and no useful x-ray data were obtained.

1960 Donald Arthur Glaser (1926–), American physicist, wins the Nobel Prize for physics for his invention of the bubble chamber for subatomic study.

1960 Rudolf Ludwig Mossbauer (1929–), German physicist, discovers how to make gamma rays with an extremely narrow wavelength that can then be used to measure very accurately any wavelength change. This becomes known as the Mossbauer effect. He then uses it to verify Einstein's relativity theory more convincingly than ever.

1960 Asbestos is identified as carcinogenic.

1960 Chlorophyll is synthesized from man-made materials.

1960 DATAPHONE becomes the first commercial modem designed specifically for converting digital computer data to analog signals for transmission across a telephone network.

1960 Frank Donald Drake (1930–), American astronomer, uses the 85.3-foot (26-m) radio telescope at the National Radio Astronomy Observatory in West Virginia to listen for possible signals from the planets of the sun-like stars Tau Ceti and Epsilon Eridani in a search for signs of extraterrestrial intelligence.

1960 Frank Macfarlane Burnet (1899–1985), Australian immunologist, and Peter Brian Medawar (1915–1987), English biologist, are awarded the Nobel Prize for physiology or medicine for the discovery of acquired immunological tolerance.

1960 Herbert Friedman (1916–2000), American astronomer, takes an x ray photograph of the sun.

1960 John Laurence Kulp (1921–2006), American chemist, announces a new, revised geologic timetable. This new chronology is based on the measurement of radioactive decay in rock specimens.

1960 Kitts Peak National Observatory is completed. Located southwest of Tucson, Arizona, it is run by the Association of Universities for Research in Astronomy and has the McMath solar tower telescope, the largest of this specialized type (which became operational in 1962). In 1973 its 158-inch (401-cm) reflecting telescope becomes operational.

1960 Lyman Creighton Craig, American chemist, isolates and purifies "parathormone," the active principle of the parathyroid gland.

1960 The first totally implantable pacemakers are introduced for human hearts.

1960 Robert Burns Woodward (1917–1979), American chemist, first synthesizes chlorophyll.

1960 Willard Frank Libby (1908–1980), American chemist, is awarded the Nobel Prize for chemistry for his method to use carbon-14 for age determination in archeology and other branches of science.

1960 Theodore Harold Maiman (1927–2007), American physicist, develops the first laser. He uses a ruby cylinder that emits a light that is coherent (all in a single direction)

and monochromatic (a single wavelength). He finds that it can travel thousands of miles as a beam without dispersing, and that it can be concentrated into a small, superhot spot. Laser is an acronym for Light Amplification by Stimulated Emission of Radiation.

1960 The first man-made object recovered from space after being in orbit around Earth is the U.S. Air Force satellite *Discoverer 13.* The instrumented satellite is recovered in the ocean near Hawaii.

1960 The first passive communications satellite, *Echo 1,* is launched into orbit by the United States. It is a large, foil-covered balloon that inflates in space and off which signals are bounced.

1961 Murray Gell-Mann (1929–), American physicist, and Israeli physicist, Yuval Ne'eman (1925–2006), independently introduce a new way to classify heavy subatomic particles. Gell-Mann names it the "eight-fold way," and this system accomplishes for elementary particles what the periodic table did for the elements.

1961 Robert Hofstadter (1915–1990), American physicist, and Rudolf Ludwig Mossbauer (1929–), German physicist, win the Nobel Prize for physics. Hofstadter wins for his pioneering studies of electron scattering in atomic nuclei and his discoveries concerning the structure of the nucleons. Mossbauer wins for his researches concerning the resonance absorption of gamma radiation and his discovery of the effect that bears his name.

1961 Robert Hofstadter (1915–1990), American physicist, announces his discovery that protons and neutrons are made up of a central core of positively charged matter, around which are two shells of mesonic material.

1961 Albert Ghiorso (1915–), American physicist, and colleagues produce element 103, and lawrencium is added to the Periodic Table.

1961 David H. Swann and H.B. Williman, American geologists, propose a new stratigraphic term, the "megagroup." It is defined as a rock-stratigraphic unit containing lithologically similar formations and ranking above a group. It is primarily a rock unit, and its upper and lower limiting surfaces may cross and recross faunal or floral zones or unconformities.

1961 Georg Von Békésy (1899–1972), Hungarian-American physicist, is awarded the Nobel Prize for physiology or medicine for his discoveries of the physical mechanism of stimulation within the cochlea. He is also the first physicist to win this prize.

1961 Irving S. Cooper (1922–1985), American neurosurgeon, first uses a freezing technique known as cryosurgery to freeze and destroy damaged tissue within the brain of patients with Parkinson's disease. This leads to cryosurgery being used in delicate eye surgery to remove cataracts from the lens of the eye as well as to repair detached retinas.

1961 Marshall Warren Nirenberg (1927–) and Severo Ochoa (1905–1993), both American biochemists, work out the beginning of the RNA messenger code. RNA contains instructions for carrying out cellular processes, and it works with DNA, which contains the organism's genetic information.

1961 Marshall Warren Nirenberg (1927–), American biochemist, synthesizes a protein molecule by using artificial DNA.

1961 Melvin Calvin (1911–1997), American biochemist, recreates the photosynthesis reaction sequence and proves that a light reaction involving chlorophyll instantly captures sunlight and converts it into chemical energy.

1961 Melvin Calvin (1911–1997), American biochemist, is awarded the Nobel Prize for chemistry for his research on carbon dioxide assimilation in plants.

1961 Francis Crick (1916–2004), English biochemist, Sydney Brenner (1927–), and others propose that a molecule called transfer RNA uses a three base code in the manufacture of proteins.

1961 French pathologist Jacques Miller (1931–) discovers the role of the thymus in cellular immunity.

1961 Marshall Warren Nirenberg (1927–) synthesizes a polypeptide using an artificial messenger RNA (a synthetic RNA containing only the base uracil) in a cell-free protein-synthesizing system. The resulting polypeptide only contains the amino acid phenylalanine, indicating that UUU was the codon for phenylalanine. This important step in deciphering the genetic code is described in the landmark paper by Nirenberg and J. Heinrich Matthaei, "The Dependence of Cell-Free Synthesis in E. coli upon Naturally Occurring or Synthetic Polyribonucleotides." This work establishes the messenger concept and a system that could be used to work out the relationship between the sequence of nucleotides in the genetic material and amino acids in the gene product.

1961 Noel Warner establishes the physiological distinction between the cellular and humoral immune responses.

1961 The first man in space and the first to orbit Earth is Soviet cosmonaut Yuri Gagarin (1934–1968). He circles Earth once in his *Vostok 1* spacecraft, which reaches 187 miles (300.9 km) above Earth. During the entire flight, the spacecraft is controlled from the ground. On reentry, Gagarin ejects at 22,000 feet (6.7 km) and parachutes down safely after his one hour, 48 minute flight. The Soviets stun and amaze the world, and the era of manned space flight begins.

1961 The first American in space is American astronaut Alan Bartlett Shepard, Jr. (1923–1998), who is launched on a suborbital trajectory by a Redstone booster rocket. He rides his *Freedom 7* space capsule to a height of 116 miles (186.7 km) and lands 297 miles (478 km) downrange in the Atlantic. He is weightless for 5 minutes of his 15 minute, 22 second flight.

1961 President John F. Kennedy (1917–1963) unveils the commitment to execute Project Apollo on this date in a speech on "Urgent National Needs," billed as a second State of the Union message.

1962 Lev Davidovich Landau (1908–1968), Russian physicist, wins the Nobel Prize for physics for his pioneering theories on condensed matter, especially liquid helium.

1962 Brian Josephson (1940–) of England obtains a patent for his superconductivity switch. Although it works ten times faster than an ordinary transistor, it must operate at a temperature near absolute zero.

1962 Bruno Benedetto Rossi (1905–1993), Italian astronomer, and colleagues discover in Scorpio the first x-ray source outside the solar system.

1962 First departments of "Computer Science" are established at Stanford and Purdue universities. They will soon become a popular undergraduate major in scores of universities.

1962 First radar observations of Mercury are made by a radio telescope in a large natural basin in Arecibo, Puerto Rico. They are also made from Russia during this year.

1962 Francis Crick (1916–2004), English biochemist, James Dewey Watson (1928–), American biochemist, and Maurice Hugh Frederick Wilkins (1916–2004), New Zealand-English physicist, are awarded the Nobel Prize for physiology or medicine for their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material.

1962 Harry Hammond Hess (1906–1969), American geologist, presents evidence for his theory of sea-floor spreading. He states that the sea floors crack open along the crest of the mid-ocean ridges and that the new sea floor forms there and spreads apart on either side of the crest. This theory becomes central to the new science of plate tectonics.

1962 Isotope carbon-12 is adopted as the official standard for atomic weights.

1962 Jacques Miller (1931–), French-Australian physician, demonstrates the important role of the thymus in immunology. If the thymus is removed at a young age, the animal does not develop antibodies and has no resistance.

1962 John Archibald Wheeler (1911–2008), American physicist, publishes his *Geometro-*

dynamics in which he considers those aspects of general relativity that suggest the possibility of gravitational collapse. He theorizes conditions under which a collapse cannot be stopped and invents the term "black hole" to describe a collapsed mass whose gravitational field becomes so intense that not even light could escape it.

1962 Max Ferdinand Perutz (1914–2002), Austrian-English biochemist and John Cowdery Kendrew (1917–1997), English biochemist, are awarded the Nobel Prize for chemistry for their studies of the structures of globular proteins.

1962 National Radio Astronomy Observatory is completed at Green Bank, West Virginia. An important U.S. center for astrophysical research, this observatory adds a fully steerable, 140-ft (43-m) radio telescope in 1965.

1962 Neil Bartlett (1932–), English chemist, successfully demonstrates that the noble gases are not incapable of reacting chemically when he forms a new noble gas compound called xenon platinofluoride.

1962 Joseph Edward Murray (1919–), American surgeon, uses a cadaver kidney and transplants it into a human subject. This is the first successful renal allograft between unrelated subjects.

1963 Eugene Paul Wigner (1902–1995), American physicist, Maria Goeppert-Mayer (1906–1972), American physicist, and Johannes Hans Danile Jensen (1907–1973), German physicist, win the Nobel Prize for physics. Wigner wins for his contributions to the theory of the atomic nucleus and the elementary particles, particularly through the discovery and application of fundamental symmetry principles. Goeppert-Mayer and Jensen win for their discoveries concerning nuclear shell structure.

1963 A successful measles vaccine is finally perfected.

1963 Allan Rex Sandage (1926–), American astronomer, discovers a suspicious object in galaxy M-82 that has a very strong radio source. His photographs show the galaxy to be undergoing an enormous explosion at its core that has been going on for 1.5 million years. This serves to confirm the theory of Victor Ambartzumian.

1963 ASCII (American Standard Code for Information Interchange) is developed to allow computers from different manufacturers to exchange data. Produced by a joint government-industry team, this is the first universal standard for computers.

1963 Daniel Carleton Gajdusek (1923–), American pediatrician, describes the first slow-virus infection to be identified in humans.

1963 Frederick J. Vine (1939–) and Drummond H. Matthews (1931–1997) are able to test the hypothesis of the continuous creation of the ocean floors by examining the magnetic pattern on both sides of an oceanic ridge. They provide magnetic data that not only show that spreading occurs but also that indicate the rate of spread.

1963 Heinz Adolf Lowenstam (1912–1993), German-American paleontologist, makes the first list of biogenic minerals.

1963 Jesse Leonard Greenstein (1909–2002), American astronomer, interprets the spectrum of a quasar and helps his colleague Maarten Schmidt (1929–) to further elucidate their strange nature as the most luminous objects in the universe. His career work on the constitution of stars, especially how they differ, contributes to knowledge of stellar evolution.

1963 John Carew Eccles (1903–1997), Australian physiologist, Alan Lloyd Hodgkin (1914–1998), English physiologist, and Andrew Fielding Huxley, English physiologist, are awarded the Nobel Prize for physiology or medicine for work on the mechanisms of nerve-impulse transmission, particularly their discoveries concerning the ionic mechanisms involved in excitation and inhibition in the peripheral and central portions of the nerve cell membrane. Eccles also offers the notion that the mind is wholly separate from the brain and acts upon the brain by making very subtle changes in the chemical signals that flow among brain cells.

1963 Karl Ziegler (1898–1973), German chemist, and Giulio Natta (1903–1979), Italian chemist, are awarded the Nobel Prize for chemistry for their discoveries in the field of the chemistry and technology of high polymers.

1963 Maarten Schmidt (1929–), Dutch-American astronomer, discovers quasi-stellar radio sources (QSO's), now called quasars. After pinpointing what appear to be invisible radio-emitting stars, he finds the spectral lines are unlike any seen before. They are finally discovered to be coming not from a star at all but from incredibly distant object like a galaxy—except that it emits more energy than an entire galaxy would. Quasars prove difficult to understand, and after thirty years of study, they appear to be better understood in terms of black hole theory. They are now considered to be massive black holes at the center of a galaxies.

1963 Thomas E. Starzl (1926–), American surgeon, performs the first human liver transplant. The recipient survives for 23 days. Such operations are still experimental, since the problem of suppressing the body's immune system is not solved.

1963 Ruth Sager (1918–1997) discovers DNA in chloroplasts. Boris Ephrussi (1901–1979) finds DNA in mitochondria.

1963 The first transatlantic satellite transmission of photographs is made from New York to Paris, Rome, and London via the U.S. communications satellite *Relay 1.*

1964 Charles Hard Townes (1915–), American physicist, and Russian physicists, Nikolay Gennadievic Basov (1922–2001) and Alexandre Mikhailovic Prokhorov (1916–2002), win the Nobel Prize for physics for their fundamental work in the field of quantum electronics, which leads to the construction of oscillators and amplifiers based on the maser-laser principle.

1964 James Watson Cronin (1931–) and Val Logsden Fitch (1923–), American physicists, show that the conservation rule of charge conjugation does not hold up, and they replace it with a still more general conservation law. This implies that time reversal does not always reverse events exactly on the subatomic level.

1964 Choh Hao Li (1913–1987), Chinese-American chemist and endocrinologist, and colleagues discover a protein they later name beta-lipotrophin. A peptide of uncertain function, it is known to be manufactured in the pituitary gland and in the same cells as ACTH.

1964 Cyril Astley Clarke (1907–2000) announces that the injection of Rh-negative mothers with Rh-antibodies successfully prevents their conceiving Rh babies.

1964 Edward Crisp Bullard (1907–1980), English geophysicist, studies Earth's crust and internal constitution and offers his theory of the geomagnetic dynamo, based on convective motion within Earth's core.

1964 Konrad Emil Bloch (1912–2000), German-American biochemist, and Feodor Lynen (1911–1979), German biochemist, are awarded the Nobel Prize for physiology or medicine for their discoveries concerning the mechanism and regulation of the cholesterol and fatty acid metabolism.

1964 Researchers at the Joint Nuclear Research Institute in Dubna, Russia, report they produced an isotope of element 104 by bombarding plutonium-242 with neon-22 nuclei. They propose the name kurchatovium in honor of Soviet nuclear physicist Igor Kurchatov (1903–1960). Element 104 is the first transactinide element, the first to begin a new, rare-earth-type row in the Periodic Table.

1964 Robert Burns Woodward (1917–1979), American chemist, is awarded the Nobel Prize for chemistry for his outstanding achievements in the art of organic synthesis.

1964 U.S. National Library of Medicine introduces a computer-based system for the analysis and retrieval of medical literature (MEDLARS).

1964 Barbara Bain publishes a classic account of her work on the mixed leukocyte culture (MLC) system that is critical in determining donor-recipient matches for organ or bone marrow transplantation. Her work

is published in *Blood in* 1964 and becomes a citation classic in *Current Contents.* Bain shows that the MLC phenomenon is caused by complex genetic differences between individuals.

1964 International Year of the Quiet Sun begins. This international program is created to exploit the minimal solar activity that will occur during the next two years.

1964 Murray Gell-Mann (1929–), American physicist, first introduces the concept of "quarks" as he postulates the existence of unusual particles that carry fractional electric charges.

1964 Arno Allan Penzias (1933–), German-American physicist, and Robert Woodrow Wilson (1936–), American radio astronomer, detect the radio-wave background (radiation coming from all directions in equal quantities) that proves to be the distant echo of the "big bang." This phenomenon had been predicted by George Gamow (1904–1968) many years earlier.

1964 The Crab Nebula supernova remnant is discovered to be a hard x-ray (15-60 keV) source by a scintillation counter detector flown on a balloon launched from Palestine, Texas. This was likely the first balloon-based detection of x rays from a discrete cosmic x-ray source.

1965 Shin'ichiro Tomonaga (1906–1979), Japanese physicist, and American physicists Richard Philips Feynman (1918–1988) and Julian Seymour Schwinger (1918–1984), win the Nobel Prize for physics for their fundamental work in quantum electrodynamics, with major consequences for the physics of elementary particles.

1965 Astronomers at Arecibo, Puerto Rico, prove that the rotation of Venus is truly retrograde or revolving in a direction different from Earth and the other planets.

c.1965 Donald Robert Coates, American geologist, produces the first mathematically computerized program to analyze a system of related variables in hydrology, geomorphology, and geology.

1965 François Jacob (1920–), French biologist, André-Michael Lwoff (1902–1994), French microbiologist, and Jacques-Lucien Monod (1910–1976), French biochemist, are awarded the Nobel Prize for physiology or medicine for their discoveries concerning genetic control of enzyme and virus synthesis.

1965 Geoffrey Harris, British anatomist, shows that sexuality is built into the hypothalamus.

1965 Gerald Stanley Hawkins (1928–2003), English-American astronomer, publishes his *Stonehenge Decoded*, in which he suggests that the famous stone structure in England was a prehistoric observatory to keep track of the movement of the sun and moon.

1965 Harold Rollin Wanless (1898–1970), American geologist, publishes his *Aerial Stereo Photographs* and pioneers photogeology. He uses aerial photographs to interpret the exposed geological features on Earth's surface.

1965 James M. Schlatter, American chemist, combines two amino acids and discovers the mixture's sweet taste. This chemical is about 200 times as sweet as sugar and is named aspartame. In 1983 it is approved for use in carbonated beverages. It becomes the most widely-used artificial sweetener.

1965 John Tuzo Wilson (1908–1993), Canadian geologist, establishes global patterns of faulting and the structure of the continents. He is the first to use the terms "plates" geologically and offers a model of their behavior in terms of plane geometry.

1965 Neutrinos from the sun are detected deep in mines in South Africa and the United States by researchers who are searching for these difficult-to-detect particles that have no mass and no electric charge. With this, neutrino astronomy begins the study of the energy producing processes of the sun.

1965 R. Dyce and Gordon H. Pettengill (1926–) at Arecibo, Puerto Rico, determine the rotation period of the planet Mercury using radar methods.

1965 Synthetic sex attractants or artificial pheromones are developed for cockroaches and other insects.

1966 Alfred Kastler (1902–1984), German-French physicist, wins the Nobel Prize for physics for his discovery and development of optical methods for studying Hertzian resonances in atoms.

1966 Amniocentesis becomes widespread as doctors now obtain fetal cells from the mother's amniotic fluid to culture them and analyze their chromosomes.

1966 Carl Edward Sagan (1934–1996), American astronomer, studies planetary atmospheres and works out a greenhouse model for the atmosphere of Venus that accounts for its puzzling high temperatures. He also finds evidence for elevation differences on the surface of Mars and for organic molecules in Jupiter's atmosphere.

1966 Choh Hao Li (1913–1987), Chinese-American chemist and endocrinologist, describes the structure of human growth hormone and first synthesizes it (1966–1971).

1966 Daniel Carleton Gajdusek (1923–), American pediatrician, transfers for the first time a viral disease of the central nervous system from humans to another species. The viral disease kuru is found in New Guinea and is spread by the ritual eating of the deceased brain's.

1966 David Burlingame Kitts, American zoologist and geologist, publishes an article in which he points out the difficulty or impossibility of measuring geologic time except by closed periodic systems (those in which periodic behavior occurs, based on the system and free from forces external to the system). Since geologic systems are not accurately closed, he recommends that geologic time be subdivided by limiting units solely at their beginning.

1966 Francis Peyton Rous (1879–1970), American physician, is awarded the Nobel Prize for physiology or medicine for his discovery of tumor-inducing viruses. Charles Brenton Huggins (1901–1997), Canadian-American surgeon, is awarded the Nobel Prize for physiology or medicine for his discoveries concerning hormonal treatment of prostatic cancer.

1966 French Academy of Medicine adopts brain activity rather than heart stoppage as a clinical sign of death.

1966 Michael Ellis DeBakey (1908–), American surgeon, designs an artificial left ventricle that he implants in a patient's heart

1966 N.L. Dobretzov of Russia and colleagues make the first metamorphic facies map of most of Europe and the entire Soviet Union.

1966 Paul D. Parman and Harry M. Myer, Jr., develop a live-virus rubella vaccine.

1966 Robert Sanderson Mulliken (1896–1986), American chemist, is awarded the Nobel Prize for chemistry for his fundamental work concerning chemical bonds and the electronic structure of molecules by the molecular orbital method.

1966 Bruce Ames (1928–) develops a test to screen for compounds that cause mutations, including those that cause cancer. The so-called Ames test utilizes the bacterium *Salmonella typhimurium.*

1967 Hans Albrecht Bethe (1906–2005), German-American physicist, wins the Nobel Prize for physics for his contributions to the theory of nuclear reactions, especially his discoveries concerning energy production in stars.

1967 V.M. Lobashov demonstrates that the strong nuclear force violates parity conservation.

1967 Arthur Kornberg (1918–2007), American biochemist, and colleagues synthesize biologically active DNA using one strand of natural DNA from a virus.

1967 Charles T. Caskey (1938–), Richard E. Marshall, and Marshall Warren Nirenberg (1927–), American biochemist, state that since amino acids, bacteria, and guinea pigs have identical forms of messenger RNA, there is a universal genetic code shared by all life forms.

1967 Charles Yanofsky (1925–), American biologist, shows for the first time that the codon (genetic code) sequence in a gene determines the sequence of amino acids in a protein.

1967 International Committee on the History of Geology holds its first meeting at Erevan, Armenia.

1967 Mammography, a new form of x-ray detection for breast cancer, is first introduced. It becomes a standard screening method.

1967 Manfred Eigen (1927–), German physicist, Ronald George Wreyford Norrish (1897–1978), English chemist, and George Porter (1920–2002), English chemist, are awarded the Nobel Prize for chemistry for their studies of extremely fast chemical reactions, effected by disturbing the equilibrium by means of very short pulses of energy.

1967 Ragnar Arthur Granit (1900–1991), Finnish-Swedish physiologist, Haldan Keffer Hartline (1903–1983), American physiologist, and George Wald (1906–1997), American chemist, are awarded the Nobel Prize for physiology or medicine for their discoveries concerning the primary physiological and chemical visual processes in the eye.

1967 René Geronimo Favaloro (1923–2000), American surgeon, performs the first coronary artery bypass utilizing a vein.

1967 Robert Helmer MacArthur (1930–1972), American organic chemist, and Edward Osborne Wilson (1929–), American zoologist, publish their work *The Theory of Island Biogeography*, which marks the beginning of equilibrium biogeography. This branch of ecology studies systems that are stable and in balance.

1967 Robert Henry Dicke (1916–1997), American physicist, discovers that the sun is not spherical.

1967 The new fertility drug clomiphene is introduced. Although it can result in multiple births, it proves very successful in increasing a woman's chances of getting pregnant.

1967 Charles Yanofsky (1925–) demonstrates that the sequence of codons in a gene determines the sequence of amino acids in a protein.

1967 The first volume of *Annual Review of Genetics* (ARG) is published, adding it to the *Annual Review* series. Volume 1 is dedicated to Hermann Joseph Muller (1890–1967).

1967 Thomas Brock (1926–), American bacteriologist, discovers the heat-loving bacterium *Thermus aquaticus* in a hot spring in Yellowstone National Park, Wyoming. The bacterium yields the enzyme that becomes the basis of the DNA polymerase reaction.

1967 Jocelyn Bell (1943–), English graduate student working with English astronomer Antony Hewish (1924–), unexpectedly notes a rapidly fluctuating but unusually regular radio signal between the stars Vega and Altair. This becomes the first known "pulsar."

1967 First successful human heart transplant is performed by South African surgeon Christiaan Neelthing Barnard (1922–2001) in South Africa. The recipient, Louis Washkansky, lives for eighteen days.

1968 Luis Walter Alvarez (1911–1988), American physicist, wins the Nobel Prize for physics for his decisive contributions to elementary particle physics, in particular the discovery of a large number of resonance states, made possible through his development of the technique of using a hydrogen bubble chamber and data analysis.

1968 Carlo Valenti, American physician, makes the first diagnosis as to whether a fetus is affected by Down's syndrome by analyzing fetal cells taken from a mother's amniotic fluid.

1968 Elso Sterrenberg Barghoorn (1915–1984), American paleontologist, and colleagues suggest that they have discovered the remains of primitive cells (amino acids) in rocks as old as 3 billion years. If this is correct, then life in some form existed on Earth for much of its 4.5 billion years.

c. 1968 Ion Gresser, American virologist, and Kari Cantell, Finnish virologist, develop a way to make interferon in useful amounts from human blood cells.

1968 Lars Onsager (1903–1976), Norwegian-American chemist, is awarded the Nobel Prize for chemistry for the discovery of the reciprocal relations bearing his name, which are fundamental for the thermodynamics of irreversible processes.

1968 Mark Steven Ptashne (1940–), American molecular biologist, and Walter Gilbert

(1932–) independently identify the first repressor genes.

1968 Robert William Holley (1922–1993), American chemist, Har Gobind Khorana (1922–), Indian-American chemist, and Marshall Warren Nirenberg (1927–), American biochemist, are awarded the Nobel Prize for physiology or medicine for their interpretation of the genetic code and its function in protein synthesis.

1968 Roger Guillemin (1924–), French-American physiologist, Roger Cecil Burgus, American biochemist, Andrew Victor Schally (1926–), American endocrinologist, and Wylie Vale, American biochemist, announce the isolation of the first known hypothalamic hormone, TRH (Thyrotropin-Releasing Hormone). They also sequence and synthesize this hormone, which is the first in the series of hormones that stimulates the thyroid gland to produce thyroxine.

1968 Second human heart transplant is performed by Christiaan Neelthing Barnard (1922–2001), South African surgeon. The patient lives for 74 days.

1968 Werner Arber (1929–) of Switzerland discovers that bacteria defend themselves against viruses by producing DNA-cutting enzymes. This understanding later proves valuable to future genetic engineering, and the enzymes quickly become important tools for molecular biologists.

1968 The first computers using integrated circuits are released—the Burroughs 2500 and the Burroughs 3500.

1968 Lynn Margulis (1938–) proposes that mitochondria and chloroplasts in eukaryotic cells originated from bacterial symbiosis.

1968 Antony Hewish (1924–), English astronomer, publishes his account of the discovery of a "pulsating star" or "pulsar" and establishes some of its main properties. This new class of pulsing radio sources beats with such great regularity that it is at first thought to be some form of communication from outer space. The suggestion by Thomas Gold (1920–2004) that it is a rapidly rotating neutron star is shown later to be correct.

1969 Murray Gell-Mann (1929–), American physicist, wins the Nobel Prize for physics for his contributions and discoveries concerning the classification of elementary particles and their interactions.

c.1969 Allan MacLeod Cormack (1924–1998) of the United States constructs the first computerized axial tomography device (CAT scan). His initial model uses a thin beam of x rays aimed at one section of the body but repeated from many different angles. However, he lacks a system to process the large amount of data produced.

1969 B. Gutte and Robert Bruce Merrifield (1921–2006) complete the chemical synthesis of ribonuclease.

1969 P. Dally of England suggests a three-scale classification of anorexia nervosa: Obsessional (O), Hysterical (H), and Mixed (M).

1969 Derek Harold Richard Barton (1918–1998), English chemist, and Odd Hassel (1897–1981), Norwegian physical chemist, are awarded the Nobel Prize for chemistry for their contributions to the development of the concept of conformation and its application in chemistry.

1969 Formaldehyde is identified as the first of a constantly growing number of organic types of molecules being found in interstellar space by radio astronomy techniques.

1969 Jonathan R. Beckwith (1935–), American molecular biologist, and colleagues succeed in isolating a single gene.

1969 Jonathan R. Beckwith isolates the lac Z gene.

1969 Max Delbrück (1906–1981), German-American microbiologist, Alfred Day Hershey (1908–1997), American microbiologist, and Salvador Edward Luria (1912–1991), Italian-American microbiologist, are awarded the Nobel Prize for physiology or medicine for their discoveries concerning the replication mechanism and the genetic structure of viruses.

1969 Peter Van de Kamp (1901–1995), Dutch-American astronomer, finds strong evidence that there exist planets orbiting stars other than our sun. He concludes from the

wobbling motion of Barnard's star that it is being orbited by a planet and not by a companion star. His ideas imply that some form of life may exist outside the solar system.

1969 Stanford Moore (1913–1982) and William Howard Stein (1911–1980), both of the United States, independently identify the active site of an enzyme (ribonuclease from bovine pancreas).

1969 Julius Adler (1930–) discovers protein receptors in bacteria that function in the detection of chemical attractants and repellents. The so-called chemoreceptors are critical for the directed movement of bacteria, which comes to be known as chemotaxis.

1969 American astronomers W. Jon Cocke, Donald J. Taylor, and Michael J. Disney make the first optical identification of a pulsar.

1969 First artificial heart is implanted in a human being. Denton A. Cooley (1920–), American surgeon, implants a mechanical heart made of silicon. This temporary device keeps the patient alive for 65 hours until a human heart is implanted to replace it. The patient dies 38 hours after this second operation due to pneumonia and kidney failure.

1969 The first ever detection of a cosmic gamma-ray burst (GRB) with positional information is achieved by the Vela 5A and Vela 5B satellites.

1969 Man first walks on the moon. The U.S. *Apollo 11* crew of Neil A. Armstrong (1930–), Edwin E. Aldrin, Jr. (1930–), and Michael Collins (1930–) achieves the national goal set by President John Fitzgerald Kennedy (1917–1963) on May 25, 1961. Armstrong first steps on the moon announcing, "That's one small step for a man, one giant leap for mankind." Aldrin joins him minutes later and they both gather lunar samples and conduct and set up experiments during their two hours outside the lunar module. The first radio and television transmissions from the surface of the moon are received on Earth. The landing and moon walk is watched live on television by millions of people worldwide.

1969 U.S. spacecraft *Apollo 11* splashes down on Earth after its historic eight-day voyage to the moon. Crew members return samples of moon rocks taken from the Sea of Tranquility. Later radiation tests show the age of these rocks to be between 2,700 and 4,700 million years. The oldest Earth rocks to date are about 4,500 million years.

1970 Hannes Olof Gösta Alfvén (1908–1995), Swedish physicist, and Louis Eugene Felix Néel (1904–2000), French physicist, win the Nobel Prize for physics. Alfvén wins for his fundamental work and discoveries in magnetohydrodynamics with fruitful applications in different parts of plasma physics. Néel wins for his fundamental work and discoveries concerning antiferromagnetism and ferrimagnetism, which lead to important applications in solid state physics.

1970 Bernard Katz (1911–2003), German-English physiologist, Ulf Svante von Euler (1905–1983), Swedish physiologist, and Julius Axelrod (1912–2004), American biochemist and pharmacologist, are awarded the Nobel Prize for physiology or medicine for their work on neurotransmitters or chemicals transmitting nerve impulses, especially their discoveries concerning the humoral transmitters in the nerve terminals and the mechanisms for their storage, release, and inactivation.

1970 Drilling in the Mediterranean Sea helps scientists to determine the history of that area. The discovery of rock salt and other minerals alien to a marine environment indicate that the Mediterranean was cut off from the Atlantic Ocean 5 to 10 million years ago. This led to extreme evaporation, which apparently killed all the salt brine. All life was killed, and rock salt was precipitated. Later movements eventually opened the Mediterranean to the Atlantic.

c.1970 Georges Ungar, Hungarian-American physiologist and pharmacologist, suggests that learning seems to involve the formation of peptides in the brain.

1970 Har Gobind Khorana (1922–), Indian-American chemist, and colleagues announce the first complete synthesis of a gene. In making analine-transfer RNA, they do not use a natural gene for a template, but assemble the gene directly from its component chemicals.

1970 Howard Martin Temin (1934–1994), American virologist, and David Baltimore (1938–), American biochemist, discover reverse transcriptase in viruses. This is an enzyme that causes RNA to be transcribed onto DNA.

1970 Implantation of the first cardiac pacemaker is accomplished.

1970 Luis Frederico Leloir (1906–1987), Argentinean chemist, is awarded the Nobel Prize for chemistry for his discovery of sugar nucleotides and their role in the biosynthesis of carbohydrates.

1970 Patrick Steptoe (1913–1988) and Robert Geoffrey Edwards (1925–), both English physicians, accomplish in-vitro fertilization in humans (test-tube babies).

1970 The first RAM chip is introduced by Intel—it is called the 1103 and has a capacity of 1024 bits.

1970 Hamilton Othanel Smith (1931–) and Kent Wilcox isolate the first restriction enzyme, HindII, an enzyme that cuts DNA molecules at specific recognition sites.

1970 Co-launch of the Vela 6A and 6B satellites, the final pair of Vela satellites that were launched in order to monitor compliance with the Limited Test Ban Treaty of 1963. Together with the Vela 5A and Vela 5B satellites, these satellites are often credited with the first discovery of the events called gamma-ray bursts (GRBs) although it was later realized that the Vela 4A and Vela 4B satellites had actually earlier detected at least one GRB in 1967.

1970 The People's Republic of China launches its first satellite into Earth orbit, using its own booster rocket. The research satellite, identified by the West as *Chicom 1*, weighs 381 pounds (173 kg).

1971 Dennis Gabor (1900–1979), Hungarian-English physicist, wins the Nobel Prize for physics for his invention and development of the holographic method.

1971 During the year, several symposia and reviews deal with the emerging notion of the petrologic aspects of plate tectonics. From this, a new concept of "petrotectonic assemblages" begins to emerge, meaning an association of rocks characteristic of a specific plate tectonic regime.

1971 Earl Wilbur Sutherland, Jr. (1915–1974), American physician and pharmacologist, is awarded the Nobel Prize for physiology or medicine for his discoveries concerning the mechanisms of the action of hormones.

1971 Edward Osborne Wilson (1929–), American zoologist, publishes *The Insect Societies*, which becomes a basic text on social insects.

1971 First computerized axial tomography (CAT) machine is installed in a hospital in Nimbledon, England. It incorporates the new design by Godfrey Newbold Hounsfield (1919–2004), English electrical engineer, who uses computers to collate the x-ray data and create a tomographic image that offers a detailed, sharp map of a particular cross-section of the body.

1971 First mass screening laboratory for heroin use is set up in Vietnam by the U.S. Army. The program, which samples urine for the drug, is later expanded to include amphetamine and barbiturate screening and serves as a model for civilian programs.

1971 Gerhard Herzberg (1904–1999), German-Canadian physical chemist, is awarded the Nobel Prize for chemistry for his contributions to the knowledge of electronic structure and geometry of molecules, particularly free radicals.

1971 Robert Burns Woodward (1917–1979), American chemist, first synthesizes vitamin B_{12}.

1971 The first diamond-bladed scalpel is introduced to surgery in Great Britain.

1971 U.S. Food and Drug Administration notifies doctors to stop prescribing DES (diethylstilbestrol) for morning sickness, because it predisposes the expectant mothers' female children to cancer of the reproductive tract.

1972 John Bardeen (1908–1992), Leon N. Cooper (1930–), and J. Robert Schrieffer (1931–), American physicists, win the Nobel Prize for physics for their jointly developed theory of superconductivity, usually called the BCS theory.

1972 Gerald Maurice Edelman (1928–), American biochemist, and Rodney Robert Porter (1917–1985), English immunologist, are awarded the Nobel Prize for physiology or medicine for their discoveries concerning the chemical structure of antibodies.

1972 Christian Boehmer Anfinsen (1916–1995), American biochemist, is awarded the Nobel Prize for chemistry for his work on ribonuclease, especially the amino acid sequence and the biologically active confirmation. Stanford Moore (1913–1982) and William Howard Stein (1911–1980), both American biochemists, are awarded the Nobel Prize for chemistry for their contribution to the understanding of the connection between chemical structure and catalytic activity of the active center of the ribonuclease molecule.

1972 Manic depression, also called "bipolar disorder," is found to be caused by an imbalance between two types of neurotransmitters that discharge adrenaline and acetylcholine.

1972 Robert C. Gallo (1937–), American cell biologist, and his colleagues identify interleukin-2, which is a factor that stimulates growth in human T-cells.

1972 The use of DDT (dichlorodiphenyltrichloroethane) is severely restricted in the United States, as it is shown to be an environmental contaminant. It reduces the bird population by producing extremely thin eggshells.

1972 Recombinant technology emerges as one of the most powerful techniques of molecular biology. Scientists are able to splice together pieces of DNA to form recombinant genes. As the potential uses, therapeutic and industrial, became increasingly clear, scientists and venture capitalists establish biotechnology companies.

1972 At the 24th International Geological Congress held in Montreal, Canada, the first scientific plenary session is devoted to the theme of "Geology and the Quality of Life." At this session, an international group of earth scientists expresses concern about conflicting needs for vast amounts of nonrenewable mineral and energy resources and for the avoidance of environmental degradation.

1973 David Politzer (1949–) discovers independently of David Gross (1941–) and Frank Wilczek (1951–) that quarks ignore each other when touching and attract each other the farther apart they are.

1973 Leo Esaki (1925–), Japanese physicist, Ivar Giaever (1929–), American physicist, and Brian D. Josephson (1940–), English physicist, win the Nobel Prize for physics. Esaki and Giaever win for their experimental discoveries regarding tunneling phenomena in semiconductors and superconductors, respectively. Josephson wins for his theoretical predictions of the properties of a supercurrent through a tunnel barrier, especially the Josephson effects.

1973 Astronomers discover complex molecules in Comet Kohoutek. Although not as spectacular as expected, it is visible to the naked eye and proves scientifically interesting. It was discovered by Lubos Kohoutek (1935–) in Hamburg, Germany.

1973 Candace Pert (1946–), American biochemist, and Solomon H. Snyder (1938–), American neuropharmacologist, discover the opiate or opiod receptor in the brain. They find that opiates attach themselves to receptor sites in the brain as their target cells.

1973 Deep sea drilling conducted in light of the new theory of plate tectonics supports the view that the mid-ocean ridges are young and spreading, so that progressively older rocks are found ever farther away from them and toward the continental margins.

1973 Ernst Otto Fischer (1918–2007), German chemist, and Geoffrey Wilkinson (1921–1996), English chemist, are awarded the Nobel Prize for chemistry for their pioneering work, performed independently, on the chemistry of the organo-metallic, so-called sandwich, compounds.

1973 First report is made claiming a circadian variation in blood melatonin levels (pineal hormone) in man. These variations affect mood and can cause the depression associated with seasonal affective disorder (SAD).

1973 Genetic engineering is actually conducted as Herbert Wayne Boyer (1936–), American microbiologist, and Stanley H. Cohen (1922–) cut DNA molecules using restriction enzymes, join them together with other enzymes, and reproduce them in the bacterium *Escherichia coli.*

1973 Karl von Frisch (1886–1982), Austrian-German zoologist, Konrad Lorenz (1903–1989), Austrian zoologist, and Nikolaas Tinbergen (1907–1988), Dutch zoologist, are awarded the Nobel Prize for physiology or medicine for their discoveries of the organization and elicitation of individual and social behavior patterns.

1973 Thomas V. Bliss confirms the neural-network theory of memory as he shows that high-speed bursts of electricity serve to strengthen the brain's neural networks.

1973 Annie Chang (1944–) and Stanley Cohen (1922–) show that a recombinant DNA molecule can be maintained and replicated in *Escherichia coli.*

1973 Concerns about the possible hazards posed by recombinant DNA technologies, especially work with tumor viruses, leads to the establishment of a meeting at Asilomar, California. The proceedings of this meeting are subsequently published by the Cold Spring Harbor Laboratory as a book entitled *Biohazards in Biological Research.*

1974 Howard M. Georgi (1947–) and Sheldon Lee Glashow (1932–) develop the first grand unified theory. This accounts for the strong, weak, and electromagnetic forces as parts of a single force that broke apart when the universe cools down after the big bang.

1974 Martin Ryle (1918–1984) and Antony Hewish (1924–), English physicists, win the Nobel Prize for physics for their pioneering research in radio astrophysics. Ryle wins for his observations and inventions of the aperture synthesis technique, and Hewish wins for his decisive role in the discovery of pulsars.

1974 Albert Claude (1899–1983), Belgian-American cytologist, Christian René De Duvé (1917–), Belgian cytologist, and George Emil Palade (1912–), Romanian-American physiologist, are awarded the Nobel Prize for physiology or medicine for their discoveries concerning the structural and functional organization of the cell.

1974 Charles T. Kowal (1940–), American astronomer, discovers the thirteenth satellite of Jupiter. He discovers another the next year.

1974 Lars Y. Terenius, Swedish neurochemist, and Agneta Wahlström, discover the existence of naturally-produced small peptides that act upon the brain's opiate receptors.

1974 The National Academy of Sciences calls for a halt in genetic engineering research until all of its implications are better understood.

1974 Paul John Flory (1910–1985), American chemist, is awarded the Nobel Prize for chemistry for his fundamental achievements in the physical chemistry of macromolecules.

1974 Stephen William Hawking (1942–), English physicist, proposes that, in accordance with the predictions of quantum theory, black holes emit subatomic particles until they exhaust their energy and finally explode. His work spurs efforts to theoretically delineate the properties of black holes.

1974 Studies of moon rocks suggest that its geology is simpler than that of Earth. It has a crust of about 40 miles (65 km) thick and is composed chiefly of anorthosite, a relatively rare, feldsparlike rock. Its mantle is believed to consist of denser rocks rich in iron and magnesium.

1974 The Food and Drug Administration bans the use of chloroform in both drugs and cosmetics. It suspects it causes cancer.

1974 Peter Doherty (1940–) and Rolf Zinkernagl (1944–) discover the basis of immune determination of self and non-self.

1974 First detection of an x-ray flare from an M dwarf star, namely the flare star YZ CMi, by the Utrecht soft-energy (0.2–0.28 keV) and medium-energy (1–7 keV) detectors on the Astronomical Netherlands Satellite (ANS).

1975 Aage Niels Bohr (1922–), Danish physicist, Benjamin Roy Mottelson (1926–), Danish-American physicist, and Leo James Rainwater (1917–1986), American physicist, win the Nobel Prize for physics for their discovery of the connection between collective motion and particle motion in atomic nuclei and the development of the theory of the structure of the atomic nucleus based on this connection.

1975 A.F. Bradbury, D.G. Smith, and C.R. Snell isolate beta-endorphin and describe its structure. It is a neurochemical that acts as the body's natural painkiller.

1975 Cesar Milstein (1927–2002) of England discovers monoclonal antibodies.

1975 David Baltimore (1938–), American biochemist, Renato Dulbecco (1914–), Italian-American virologist, and Howard Martin Temin (1934–1994), American oncologist, are awarded the Nobel Prize for physiology or medicine for their discoveries concerning the interaction between tumor viruses and the genetic material of the cell.

1975 Geologists believe that after three quarters of a century of mild conditions, Earth's climate is cooling and may be one-sixth of the way into the next period of glaciation.

1975 John Hughes (1942–) of Scotland and others discover the first known endogenous opioid peptide, enkephalin (popularly called "brain morphine"). This substance occurs naturally in the brain and suggests that the brain's chemicals can block the transmission of pain signals.

1975 John Warcup Cornforth (1917–), Australian-English chemist, is awarded the Nobel Prize for chemistry for his work on the stereochemistry of enzyme-catalyzed reactions. Vladimir Prelog (1906–1998), Croatian-Swiss chemist, is also awarded the Nobel Prize for chemistry for his research into the stereochemistry of organic molecules and reactions.

1976 Burton Richter (1931–) and Samuel Chao Chung Ting (1936–), American physicists, win the Nobel Prize for physics for their pioneering work in the discovery of a heavy elementary particle of a new kind.

1976 Baruch Samuel Blumberg (1925–) and Daniel Carleton Gajdusek (1923–), both American physicians, are awarded the Nobel Prize for physiology or medicine for their discoveries concerning new mechanisms for the origin and dissemination of infectious diseases.

1976 Donald Howard Menzel (1901–1976), American astronomer, completes his definitive survey of reports of unidentified flying objects (UFO's) and concludes that there is no evidence to support such claims. His work is published the following year as *The UFO Enigma: The Definitive Explanation of the UFO Phenomenon.*

1976 First commercial business to develop genetically-engineered products, Genentech, is formed in California.

1976 Har Gobind Khorana (1922–), Indian-American chemist, and colleagues build a functional, synthetic gene that has a complete system of regulatory mechanisms.

1976 Martin F. Gellert (1929–), Czechoslovakian-American biochemist, and colleagues discover the enzyme (gyrase) that causes the DNA double helix to form a larger helix called a supercoil.

1976 Roger Guillemin (1924–), French-American physiologist, discovers alpha-endorphin.

1976 The planet Pluto is found to be at least partially covered by frozen methane. It is detected spectroscopically.

1976 U.S. publishing firm Van Nostrand Reinhold issues the first edition of its *Encyclopedia of Computer Science.*

1976 William Nunn Lipscomb, Jr. (1919–), American chemist, is awarded the Nobel Prize for chemistry for his studies on the structure of boranes, illuminating problems of chemical bonding.

1976 First outbreak of Ebola virus is observed in Zaire, Africa. There are more than 300 cases, with a 90% death rate.

1976 Jean-François Borel (1933–), a microbiologist at the Swiss pharmaceutical firm Sandoz, publishes the structure and properties of a new immunosuppresant called cyclosporin A. This leads to clinical trials. He first discovered cyclosporin in 1969 when he took soil samples containing a fungus from southern Norway where he was vacationing.

1976 U.S. unmanned spacecraft *Viking 2* touches down on Mars and transmits the first pictures of its rocky surface. It also shows a deeply pitted surface covered by very fine soil. Surface temperatures range from −114° F (−81.1° C) to −23° F (−30.6° C). Analysis of the photos reveals that massive flows of water have at one time coursed across the Martian surface.

1977 Philip Warren Anderson (1923–), American physicist, Nevill Francis Mott (1905–1996), English physicist, and John Hasbrouck Van Vleck (1899–1980), win the Nobel Prize for physics for their fundamental investigations of the electronic structure of magnetic and disordered systems.

1977 Andreas R. Gruentzig (1939–1985) develops a method of unclogging diseased arteries called angioplasty.

1977 Earliest known AIDS (acquired immunodeficiency syndrome) victims in the United States are two homosexual men in New York who are diagnosed as suffering from Kaposi's sarcoma.

1977 Floyd Elliott Bloom (1936–), American neurobiologist, first pinpoints the location of endorphins in the pituitary gland.

1977 Herbert A. Simon (1916–2001), American computer scientist, creates BACON, an artificial intelligence program that rediscovers the fundamental laws of science.

1977 Ilya Prigogine (1917–2003), Russian-Belgian physical chemist, is awarded the Nobel Prize for chemistry for his contributions to nonequilibrium thermodynamics, particularly the theory of dissipative structures.

1977 International Business Machines Corporation (IBM) has its Data Encryption Standard (DES) adopted by the U.S. government. This method requires an eight-number key for scrambling and unscrambling data and allows the government to protect the confidentiality of unclassified computer data.

1977 A joint U.S.-Japan expedition at the U.S. base station near McMurdo Sound in Antarctica discovers concentrations of meteorites weighing 1014 pounds (460 kg) that have been long-buried and were eventually brought to the ice surface.

1977 Keiichi Itakura (1942–), Japanese-American molecular biologist, demonstrates how to inhibit the release of growth hormone from rat pituitary cells.

1977 Philip Allen Sharp (1944–) and Richard John Roberts (1943–) independently discover that the DNA making up a particular gene could be present in the genome as several separate segments. Although both Roberts and Sharp use a common cold-causing virus, called adenovirus, as their model system, researchers later find "split genes" in higher organisms, including humans. Sharp and Roberts are subsequently awarded the Nobel Prize in medicine or physiology in 1993 for the discovery of split genes.

1977 Philip Allen Sharp (1944–) and Richard John Roberts (1943–), both American molecular biologists, independently discover that in higher organisms, there are sections of DNA that have substantial amounts of meaningless information (called introns) that are discarded in making proteins.

1977 Roger Guillemin (1924–), French-American physiologist, and Andrew Victor Schally (1926–), Polish-American biochemist, are awarded the Nobel Prize for physiology or medicine for their discoveries concerning the peptide hormone production of the brain. Rosalyn Sussman Yalow (1921–), American biophysicist, is awarded the Nobel Prize for physiology or medicine for the develop-

ment of radio-immunoassays of peptide hormones.

1977 Frederick Sanger (1918–) English biochemist, reports the sequencing of the complete genetic information of a microorganism.

1977 Carl R. Woese (1928–) and George E. Fox (1945–) publish an account of the discovery of a third major branch of living beings, the Archaea. Woese suggests that an ribosomal RNA (rRNA) database could be used to generate phylogenetic trees.

1977 Holger Windekilde Jannasch (1927–1998) demonstrates that heat-loving bacteria found at hydrothermal vents are the basis of an ecosystem that exists in the absence of light.

1977 The last reported smallpox case is recorded.

1977 James Ludlow Elliot (1943–), American astronomer, and colleagues discover that the planet Uranus is surrounded by a series of concentric rings. While they are similar to those of Saturn, they are in no way as large and bright.

1977 Charles T. Kowal (1940–), American astronomer, discovers the extraordinary object named Chiron. This is no ordinary asteroid, since its path lies mainly between the orbits of Saturn and Uranus. It is still not known what Chiron exactly is. It could be an exceptional asteroid, a planetesimal, or even an escaped satellite of Saturn.

1978 Peter Leonidovich Kapitsa (1894–1984), Russian physicist, Arno Allan Penzias (1933–), American physicist, and Robert Woodrow Wilson (1936–), American astrophysicist, win the Nobel Prize for physics. Kapitsa wins for his basic inventions and discoveries in the area of low-temperature physics. Penzias and Wilson win for their discovery of cosmic microwave background radiation.

1978 First test-tube baby is born in England. This is the first human being conceived outside the human body to be born. The fertilized egg was implanted by English physicians Patrick Steptoe (1913–1988) and Robert Geoffrey Edwards (1925–) in the mother's uterus and developed normally.

1978 Floyd Elliott Bloom (1936–), American neurobiologist, Roger Guillemin (1924–), French-American physiologist, Jean Rossier (1944–), and Yoshio Hosobuchi report that when pain in humans is relieved through electrical stimulation of part of their brains, the brain levels of beta-endorphin-like substances rise.

1978 Gerry Neugebauer (1932–), American astronomer, obtains the first Earth-based photo of the rings of Uranus. He uses the Hale reflector at Palomar Observatory in California. Although the photo does not show the rings separately, it does confirm that there are nine narrow rings around the planet.

1978 Peter Dennis Mitchell (1920–1992), English chemist, is awarded the Nobel Prize for chemistry for his contribution to the understanding of biological energy transfer through the formulation of the chemiosmotic theory.

1978 The World Health Organization (WHO) declares smallpox eradicated worldwide.

1978 Stephen Coplan Harrison (1943–), American biochemist, details the first high-resolution structure of an intact virus while studying the tomato bushy stunt virus.

1978 The first attempt to mine the deep ocean floor for manganese nodules begins in the central Pacific Ocean. It is under the management of an international consortium of mining companies (U.S., Canada, West Germany, and Japan).

1978 The U.S. drug companies Genentech and Eli Lilly announce the production of human insulin by genetic engineering.

1978 Werner Arber (1929–), Swiss microbiologist, Daniel Nathans (1928–1999), American microbiologist, and Hamilton Othanel Smith (1931–), American microbiologist, are awarded the Nobel Prize for physiology or medicine for the discovery of restriction enzymes and their application to problems of molecular genetics.

1978 Scientists from Genentech clone the gene for human insulin.

1978 Somatostatin becomes the first human hormone produced by using recombinant DNA technology.

1978 Walter Gilbert (1932–) and others establish Biogen, a pioneering biotechnology company.

1978 David Botstein (1942–), Ronald Wayne Davis (1941–), and Mark H. Skolnick (1946–) announce the potential for using DNA sequencing to develop gene markers for certain genetic diseases.

1978 The first natural satellite of an asteroid is discovered orbiting the asteroid Herculina.

1978 James W. Christy (1938–), American astronomer, discovers a satellite of Pluto, which he names Charon. It is about 750 miles (1207 km) in diameter and has ten percent the mass of Pluto.

1979 Sheldon Lee Glashow (1932–), American physicist, Abdus Salam (1926–1996), Pakistani physicist, and Steven Weinberg (1933–), American physicist, win the Nobel Prize for physics for their contributions to the theory of the unified weak and electromagnetic interaction between elementary particles, including their prediction of the weak and neutral current.

1979 Allan Macleod Cormack (1924–1998), South African-American physicist, and Godfrey Newbold Hounsfield (1919–2004), English electrical engineer, are awarded the Nobel Prize for physiology or medicine for the development of computed tomography (CT).

1979 Bulimia nervosa is described by G.F.M. Russell (England).

1979 First observation is made of a comet hitting the sun.

1979 Herbert Charles Brown (1912–2004), English-American chemist, and George Friedrich Wittig (1897–1987), German chemist, are awarded the Nobel Prize for chemistry for their development of the use of boron- and phosphorous-containing compounds, respectively, into important reagents in organic synthesis.

1979 The U.S. Geological Survey celebrates its centennial this year. Its original responsibility was to classify public lands and to examine the geologic structure, mineral resources, and products of the nation. It greatly expands and becomes a powerful influence on geologic and geochemical research.

1979 *Voyager 1* makes its closest approach (217,480 miles; 350,000 km; or 4.89 Jupiter radii) to the planet Jupiter before proceeding on to a flyby of Saturn.

1980 Heinrich Rohrer (1933–) and Gerd Binnig (1947–) invent the scanning tunneling microscope (STM). This uses electron tunneling from a sharp point that is moved over a surface to detect the distance of the point from that surface. It can provide pictures of individual atoms.

1980 James Watson Cronin (1931–) and Val Logsdon Fitch (1923–), American physicists, win the Nobel Prize for physics for their discovery of violations of fundamental symmetry principles in the decay of neutral K-mesons.

1980 A thin atmosphere covering the planet Pluto is discovered. It is believed to be composed of methane with a density about one-millionth that of Earth's air. It is created when the surface methane ice evaporates.

1980 Baruj Benacerraf (1920–), Venezuelan-American immunologist, Jean Baptiste Gabriel Joachim Dausset (1916–), French hematologist and immunologist, and George Davis Snell (1903–1996), American geneticist, are awarded the Nobel Prize for physiology or medicine for their discoveries concerning genetically determined structures on the cell surface that regulate immunological reactions.

1980 Charles Weissmann (1931–) of Switzerland successfully produces the first genetically engineered human interferon in bacteria, making large-scale production possible.

1980 Lithotripter, a device that pulverizes kidney stones with sound waves (without any surgery), is invented in West Germany by Dornier Medical Systems.

1980 Luis Walter Alvarez (1911–1988), American physicist, and his colleagues discover an unusually high concentration of iridium

at a sedimentary layer that marks the Cretaceous-Tertiary boundary. Since this time frame coincides with that of the disappearance of the dinosaurs, he speculates that a giant asteroid collided with earth, causing a prolonged dust-blackout and mass extinctions.

1980 Paul Berg (1926–), American biochemist, is awarded the Nobel Prize for chemistry for his fundamental studies of the biochemistry of nucleic acids, with particular regard to recombinant DNA. Walter Gilbert (1932–), American microbiologist, and Frederick Sanger (1918–), English biochemist, are also awarded the Nobel Prize for chemistry for their contributions concerning the determination of base sequences in nucleic acids.

1980 The Supreme Court rules that a living organism developed by General Electric (a microbe that helps clean up an oil spill) can be patented.

1980 Leroy Hood (1938–) develops the first automated DNA sequencing machine.

1980 Martin Cline (1934–) and colleagues successfully transfer a gene from one mouse to another and have the gene continue to function, constructing a transgenic mouse.

1980 Researchers successfully introduce a human gene that codes for the protein interferon into a bacterium.

1980 Mt. St. Helens, a volcanic peak in the Cascade Range of the U.S. Pacific Northwest, erupts spectacularly. Within seconds of a magnitude 5.0 earthquake, an explosion occurs that rivals Vesuvius and Pelee. It is then followed by the separation of the entire north face, which results in a catastrophic avalanche. The blast sets nearby rivers steaming from hot debris and flattens thousands of acres of timber while creating a boiling cloud of volcanic ash that fills the sky for hundreds of miles.

1981 Nicolaas Bloembergen (1920–), Dutch-American physicist, Arthur Leonard Schawlow (1921–1999), American physicist, and Kai Manne Borje Siegbahn (1918–2007), Swedish physicist, win the Nobel Prize for physics. Bloembergen and Schawlow win for their contribution to the development of laser spectroscopy. Siegbahn wins for his contribution to the development of high-resolution electron spectroscopy.

1981 AIDS (acquired immunodeficiency syndrome) is officially recognized by the U.S. Centers for Disease Control, and the first clinical description of this disease is made. It soon becomes recognized that AIDS is an infectious disease caused by a virus that is spread virtually exclusively by infected blood or body fluids.

1981 First transfer of genes from one animal to another species is accomplished.

1981 Karl Oskar Illmensee (1939–) clones baby mice.

1981 Kenichi Fukui (1918–1998), Japanese chemist, and Roald Hoffmann (1937–), Polish-American chemist, are awarded the Nobel Prize for chemistry for their theories, developed independently, concerning the course of chemical reactions.

1981 Researchers in China successfully clone a fish.

1981 Results published from the Deep Sea Drilling Project's exploration of the Blake Bahama Basin reveal that the early spreading rate of the North Atlantic Ocean is 1.48 inches (3.76 cm) per year, almost twice the previously accepted rate of 0.8 inches (2 cm) per year. The new rate is based on the age of the sediments covering the basaltic ocean basement, which at 155 million years are the oldest sediments yet recovered in the program.

1981 Roger Wolcott Sperry, American neurobiologist, shares a Nobel Prize for physiology or medicine for his "split-brain" discoveries, begun in 1961, that concern the functional specialization of the cerebral hemispheres. David Hunter Hubel (1926–), Canadian-American neurobiologist, and Torsten Nils Wiesel (1924–), Swedish neurobiologist, are also awarded the Nobel Prize for physiology or medicine for their discoveries concerning information processing in the visual system.

1981 Bill Gates (1955–) is asked in an interview about computer memory—he states that "640K ought to be enough for anybody." Typical home computers in 2001 had upwards of 128 megabytes of RAM. By 2007, it was 2 gigabytes.

1981 Some of the first viruses found outside of computer laboratories are found in the Apple II operating system; the viruses are called Apple 1, 2, 3, etc. These viruses are spread through pirated computer games.

1981 Astronauts John W. Young (1930–) and Robert L. Crippin (1937–) fly Space Shuttle *Columbia* on the first flight of the Space Transportation System (STS-1). *Columbia*, which takes its name from three famous vessels including one of the first U.S. Navy ships to circumnavigate the globe, became the first airplane-like craft to land from orbit for reuse when it touched down at Edwards Air Force Base in southern California at approximately 10:21 a.m. Pacific Standard Time on April 14 after a flight of 2 days, 6 hours, and almost 21 minutes. The mission also was the first to employ both liquid- and solid-propellant rocket engines for the launch of a spacecraft carrying humans.

1982 Kenneth Geddes Wilson (1936–), American theoretical physicist, wins the Nobel Prize for physics for his theory on critical phenomena in connection with phase transitions.

1982 Aaron Klug (1926–), English chemist, is awarded the Nobel Prize for chemistry for his development of crystallographic electron microscopy and his structural elucidation of biologically important nuclei acid-protein complexes.

1982 First brain tissue transplants are used for Parkinson's disease. They are not successful in alleviating the condition.

1982 The Food and Drug Administration approves the first genetically engineered drug. Eli Lilly & Company is permitted to market human insulin that is produced by bacteria.

1982 Gene from one mammal (rat growth hormone gene) functions for the first time in another mammal (a mouse). The mouse grows to twice its normal size.

1982 Martin Benfey and Albert Aguayo (1934–), both Canadian researchers, show that damaged brain cells can be persuaded to regrow.

1982 Mobile telephones using cellular radio technology begin to come into use.

1982 New surgical technique for prostate cancer that does not result in impotency is developed by Patrick Walsh.

1982 Oncogenes or cancer-causing genes are discovered.

1982 Scientists fit the geology of mountain-building belts or orogens into the concept of plate tectonics. They classify the world's mountains into three types, controlled by (1) continental collision, (2) subduction of oceanic lithospheric plates beneath continental lithosphere, or (3) subduction of oceanic plates beneath oceanic lithosphere. Collision orogens are represented by the Alpine and Himalayan Andes, continental-margin orogens by the Andes, and arc-trench orogens by the Aleutian Islands.

1982 Sune K. Bergström (1916–2004), Swedish biochemist, Bengt Ingemar Samuelsson (1934–), Swedish biochemist, and John Robert Vane (1927–2004), English biochemist, are awarded the Nobel Prize for physiology or medicine for their discoveries concerning prostagladins and related biologically active substances.

1982 Thomas Cech (1947–) discovers ribozymes. Within a year, Sidney Altman (1939–) also reports the discovery of RNAs with catalytic properties.

1982 A. Wright and D. Jauncey, astronomers in New South Wales, discover the most remote object to date. They observe the quasar PKS 2000-330, estimated at 13,000 million light years away.

1982 Halley's Comet is first recorded by Hale Observatory in Palomar, California. The famous comet is first sighted nearly four years before it completes its 76-year journey past Earth.

1982 Publication date of the discovery of the first millisecond pulsar, exciting astronomers around the world.

1982 First Jarvik 7 artificial heart is implanted by William DeVries (1933–), American surgeon. The patient, Barney Clark, lives for 112 days.

1983 Subramanyan Chandrasekhar, Indian-American physicist, and William Alfred Fowler, American physicist, win the Nobel Prize for physics. Chandrasekhar wins for his theoretical studies of the physical processes of importance to the structure and evolution of the stars. Fowler wins for his theoretical and experimental studies of the nuclear reactions of importance in the formation of the chemical elements in the universe.

1983 Barbara McClintock (1902–1992), American geneticist, is awarded the Nobel Prize for physiology or medicine for her discovery of mobile genetic elements.

1983 Blood is drawn through the umbilical cord from an unborn fetus and is used for the first time to diagnose a disease.

1983 First artificial chromosome is created by Andrew W. Murray and Jack William Szostak (1952–), Canadian biochemist, who work with yeast.

1983 G.L. Collingridge (1955–) shows that chemically blocking the brain's NMDA (N-methyl-D-aspartate) receptors impairs memory.

1983 Henry Taube (1915–2005), Canadian-American chemist, is awarded the Nobel Prize for chemistry for his work on mechanisms of electron transfer reactions, especially in metal complexes.

1983 Nancy Wexler (1945–) and James Gusella (1952–) discover a gene marker for Huntington's chorea.

1983 Researchers discover a gene marker for Duchenne muscular dystrophy.

1983 Researchers discover that a bacterium causes ulcers of the stomach and small intestine. This leads to a major reevaluation of such factors as stress and diet in the treatment of ulcers.

1983 Robert A. Berner (1935–), American geochemist, Antonio C. Lasaga (1949–), Cuban-American chemical physicist, and Robert M. Garrels (1916–1988) publish a computer model indicating that the carbon dioxide content of the atmosphere is highly sensitive to changes in the rate of sea floor spreading and continental area, indicating that plate tectonics is a major factor in the world's climate.

1983 The fastest-vibrating pulsar is discovered in the constellation Vulpecula. It is found to be spinning at 642 times a second.

1983 The immunosuppressant drug cyclosporine is approved by the U.S. Food and Drug Administration. This wonder-drug, made from a fungus found in the soil of Norway (and later Wisconsin), makes organ transplantation a viable operation when used in conjunction with cortisone. It is a potent immunosuppressant but must be taken by transplant recipients indefinitely. It also has many side effects.

1983 Los Alamos National Laboratory, a Department of Energy Laboratory (LANL), and Lawrence Livermore National Laboratory, a Department of Energy Laboratory (LLNL), begin production of DNA clone (cosmid) libraries representing single chromosomes.

1983 *Escherichia coli* O157:H7 is identified as a human pathogen.

1983 Luc Montagnier (1932–) and Robert C. Gallo (1937–) discover the human immunodeficiency virus that is believed to cause acquired immunodeficiency syndrome (AIDS).

1983 Launch of Astron, a joint Soviet-French observatory that carries both UV and x-ray instruments.

1983 First observation of an ionospheric disturbance due to a gamma-ray burst (GRB), detected by its effect on very low frequency (VLF) radio signals.

1984 Carlo Rubbia (1934–), Italian physicist and Simon van der Meer (1925–), Dutch engineer and physicist, win the Nobel Prize for physics for their decisive contributions to the large project that led to the discovery of the field particles W and Z, communicators of weak interaction.

1984 Allan Charles Wilson (1934–1991), American biochemist, and Russell Higuchi first

clone genes from an extinct species, as they take a gene from the preserved skin of a quagga, a type of zebra.

1984 Bruce Forbes Bohor (1932–), American geologist, and colleagues report that quartz grains in the Cretaceous-Tertiary boundary clay layer in Montana have features typical of shock metamorphism, which they interpret as compelling evidence for a high-velocity impact on Earth.

1984 C. Chopin of the United States makes the first discovery of coesite (a high-pressure form of silica) in a metamorphic rock. It does not occur naturally in Earth's crust.

1984 Eric Block and Saleem Ahmad of the United States synthesize ajoene. Found naturally in garlic, this compound is believed to have blood-thinning properties.

1984 First baby is born from a frozen embryo.

1984 First successful gene-therapy is accomplished in a mammal.

1984 Niels Kai Jerne (1911–1994), Danish-English immunologist, Georges J.F. Köhler (1946–1995), German immunologist, and César Milstein (1927–2002), Argentinian immunologist, are awarded the Nobel Prize for physiology or medicine for theories concerning the specificity in development and control of the immune system and the discovery of the principle for production of monoclonal antibodies.

1984 Robert Bruce Merrifield (1921–2006), American biochemist, is awarded the Nobel Prize for chemistry for his development of methodology for chemical synthesis on a solid matrix.

1984 Steen Willadsen successfully clones sheep via nuclear transfer.

1984 William H. Clewall, American surgeon, performs the first successful surgery on a fetus in utero.

1984 The U.S. Department of Energy (DOE), Office of Health and Environmental Research, U.S. Department of Energy (OHER, now Office of Biological and Environmental Research), and the International Commission for Protection Against Environmental Mutagens and Carcinogens (ICPEMC) cosponsor the Alta, Utah, conference highlighting the growing role of recombinant DNA technologies. The Office of Technology Assessment incorporates the proceedings of the meeting into a report acknowledging the value of deciphering the human genome.

1984 First detection of x-ray emission during the outburst of a classical nova, by the EXOSAT Low Energy (LE) telescopes.

1984 Svetlana Savitskaya (1942–) of the USSR becomes the first woman to walk in space on a mission for the Salyut 7 space station.

1985 Klaus von Klitzing (1943–), German physicist, wins the Nobel Prize for physics for his discovery of the quantized Hall effect.

1985 Alec Jeffreys (1959–) first develops a method of "fingerprinting" with DNA. He shows there are certain core sequences of DNA that are unique to each individual.

1985 Construction begins on what, at the time, is the world's largest telescope, the W.M. Keck Telescope on Mauna Kea, Hawaii. Supported by the University of California, it eventually measures twice the size of the Hale in diameter with four times its light-gathering power.

1985 Gene marker for cystic fibrosis is found on chromosome 7.

1985 Gene marker for polycystic kidney disease is found on chromosome 16.

1985 Herbert Aaron Hauptman (1917–), American mathematician and crystallographer, and Jerome Karle (1918–), American crystallographer, are awarded the Nobel Prize for chemistry for their outstanding achievements in the development of direct methods for the determination of crystal structures.

1985 Implantable defibrillator is approved by the U.S. Food and Drug Administration. This regulatory device is used to maintain a correct heartbeat and is surgically implanted.

1985 Lasers are used for the first time to unblock clogged arteries.

1985 Michael Stuart Brown (1941–) and Joseph Leonard Goldstein (1940–), both American molecular geneticists, are awarded the Nobel Prize for physiology or medicine for

their discoveries concerning the regulation of cholesterol metabolism.

1985 The U.S. research drilling ship *JOIDES Resolution* makes its first working cruise as it replaces the ship *Glomar Challenger*. Featuring a six-story laboratory and a drilling derrick 200 feet (60 m) high, it can drill in water up to 27,000 feet (8,200 m) deep. The ship replacement is part of a larger change in which the Ocean Drilling Program (ODP) succeeds the fifteen-year old Deep Sea Drilling Project.

1985 This year marks the first commercial release of the programming language C++, developed by Bjarne Stroustrup (1950–) of Bell Laboratories.

1985 Kary Mullis (1944–), who was working at Cetus Corporation, develops the polymerase chain reaction (PCR), a new method of amplifying DNA. This technique quickly becomes one of the most powerful tools of molecular biology. Cetus patented PCR and sold the patent to Hoffman-LaRoche in 1991.

1985 American molecular biologist and physician Leroy Hood (1938–) leads a team that discovers the genes that code for the T cell receptor.

1985 Elizabeth Blackburn (1948–) and Carol Greider (1961–) discover the enzyme telomerase, an unusual RNA-containing DNA polymerase that can add to the telomeres (specialized structures found at the ends of chromosomal DNA). Telomeres appear to protect the integrity of the chromosome. Most normal somatic cells lack telomerase, but cancer cells have telomerase activity, which might explain their ability to multiply indefinitely.

1985 Japanese molecular biologist Susumu Tonegawa (1939–) discovers the genes that code for immunoglobulins. He receives the 1986 Nobel Prize in physiology or medicine for this discovery.

1985 U.S. Food and Drug Administration approves the marketing of the genetically-engineered growth hormone.

1986 Ernst August Friedrich Ruska (1906–1988), German physicist, Gerd Binnig (1947–), German physicist, and Heinrich Rohrer (1933–), Swiss physicist, win the Nobel Prize for Physics. Ruska wins for his fundamental work in electron optics and for his design of the first electron microscope. Binnig and Rohrer win for their design of the scanning tunneling microscope.

1986 Karl Alex Müller (1927–) and Johannes Georg Bednorz (1950–) discover an oxide combination that, at 30° Kelvin (or 30 degrees above absolute zero), is the highest known temperature for superconductivity yet reached.

1986 AIDS (acquired immunodeficiency syndrome) virus is isolated. Called the human immunodeficiency virus (HIV), it is part of a group of viruses known as retroviruses. No cure or vaccine has yet become available.

1986 Dudley Robert Herschbach (1932–), American chemist, Yuan Tseh Lee (1936–), Chinese-American chemist, and John Charles Polanyi (1929–), American chemist, are awarded the Nobel Prize for chemistry for their contributions concerning the dynamics of chemical elementary processes.

1986 First gene known to inhibit growth is produced by an American team led by molecular biologist Robert A. Weinberg (1942–). The gene is able to suppress the cancer retinoblastoma.

1986 First genetically-engineered vaccine approved for human use is the hepatitis B vaccine. The U.S. Food and Drug Administration gives its approval.

1986 The U.S. Department of Agriculture (USDA) approves the release of the first genetically altered virus as well as the first outdoor test of genetically altered plants. The virus is to be used to combat swine herpes and the plants are high-yield tobacco plants.

1986 First license to market a living organism that was produced by genetic engineering is granted by the U.S. Department of Agriculture. It allows Biologics Corporation to sell a virus that is used as a vaccine against a herpes disease in pigs.

1986 International Committee on the Taxonomy Viruses officially names the AIDS virus as HIV (human immunodeficiency virus).

1986 Laverne Duane Kulm, American oceanographer, and colleagues publish the first detailed report of the colonies of clams and tube worms, together with mineral precipitates, that are associated with the venting of cool fluids at ocean depths of about 6561.7 feet (2,000 m) in the subduction zone where the Pacific Plate is sinking below Oregon. This demonstrates that fluids and gases emerge not only from continents but also from the ocean floor.

1986 Louis Kunkel and colleagues identify the defective gene responsible for Duchenne muscular dystrophy.

1986 Stanley Cohen (1922–), American biochemist, and Rita Levi-Montalcini (1909–), Italian-American neurologist, are awarded the Nobel Prize for physiology or medicine for their discovery of growth factors.

1986 Following a Santa Fe, New Mexico, conference, the Department of Energy officially initiates the Human Genome Initiative. Pilot projects at Department of Energy national laboratories were given a budget of $5.3 million to develop critical resources and technologies.

1986 Halley's Comet returns past Earth and becomes the first comet to be studied from close range (by satellites). Five space probes are orbited, two Japanese, two Russian, and one European, to study Halley from space. On this date, the European spacecraft *Giotto* passes within 375.9 feet (605 km) of the comet's nucleus. Data obtained from these studies generally confirm the "dirty snowball" theory, stating that its nucleus is composed of rocky fragments held together with ices such as frozen methane, ammonia, carbon dioxide and water.

1986 Teams of physicists in the United States and Germany independently observe for the first time individual quantum jumps in individual atoms.

1987 Johannes Georg Bednorz (1950–), German physicist, and Karl Alex Müller, Swiss physicist, win the Nobel Prize for physics for their important breakthrough in the discovery of superconductivity in ceramic materials.

1987 Michael K. Moe (1937–), Alan A. Hahn, and Steve R. Elliot establish that selenium-82 has the longest half-life yet measured at $-1.1 \times 1{,}020$ years.

1987 A significant advance in geologic mapping and sedimentary basin analysis is reported by a group of U.S. scientists who develop and apply a new remote-sensing approach to stratigraphy and structural mapping. They use multispectral image data acquired from aircraft and satellites, combined with topographic data, to determine the attitude, sequence, thickness, and character of sedimentary strata exposed at the surface in the Wind River and Big Horn basins of Wyoming.

1987 Artificial chromosomes are produced.

1987 David C. Page and colleagues discover the gene responsible for maleness in mammals. It is a single gene on the Y chromosome that leads to the development of testes rather than ovaries.

1987 Defective genes are linked to colon cancer by Walter Bodmer (1936–), Ellen Solomon, H.J.R. Bussey, and A.J. Jeffreys.

1987 Donald James Cram (1919–2001), American chemist, Jean-Marie Lehn (1939–), French chemist, and Charles John Pedersen (1904–1989), American chemist, are awarded the Nobel Prize for chemistry for their development and use of molecules with structure-specific interactions of high selectivity.

1987 Gene marker is identified that causes a hereditary form of Alzheimer's disease.

1987 Genetically engineered plants are first developed.

1987 Ignacio Navarro Madrazo implants cells from the adrenal gland and alleviates Parkinson's disease.

1987 Susumu Tonegawa (1939–), Japanese molecular biologist, is awarded the Nobel Prize for physiology or medicine for his discovery of the genetic principle for generation of antibody diversity.

1987 The first criminal conviction is obtained on the basis of genetic information evidence. Following this landmark use of DNA or "genetic fingerprinting" in England, genetic evidence becomes increasingly admissible and accepted in a court of law.

1987 Maynard Olson creates and names yeast artificial chromosomes (YACs), which provide a technique to clone long segments of DNA.

1987 The Congress-chartered Department of Energy advisory committee, Health and Environmental Research Advisory Committee (HERAC), recommends a 15-year, multidisciplinary, scientific, and technological undertaking to map and sequence the human genome. DOE designates multidisciplinary human genome centers. National Institute of General Medical Sciences at the National Institutes of Health (NIH NIGMS) begins funding genome projects.

1987 Launch of the third Japanese x-ray astronomy satellite Ginga, known as Astro C prior to launch.

1987 Ian Shelton observes a supernova in the Large Cloud of Magellan. Called Supernova 1987A, it is the nearest supernova visible from Earth since 1604.

1987 First test of free-living, genetically engineered bacteria is conducted as strawberry fields are sprayed with bacteria whose ice-forming gene has been eliminated.

1987 Detection of gamma-ray emission lines produced by the radioactive decay of the Cobalt 56 isotope from the direction of the supernova SN 1987A, by the Solar Maximum Mission Gamma-Ray Spectrometer. The detection of these lines at 837 and 1238 keV was a triumphant confirmation of the theory that the optical light curves of supernovae in the later stages are powered by the nucleosynthesis of Iron 56 from Cobalt 56 (which itself is produced by the radioactive decay of Nickel 56).

1987 Michael Zasloff announces the discovery of new antibiotics obtained from the skin of the African clawed frog. He names them magainins.

1987 Kevin P. Campbell (1952–) and Roberto Coronado announce their discovery of the key step in muscle contraction and relaxation. They locate a protein that regulates the flow of calcium in and out of muscle cells and name it the calcium release channel.

1988 Leon Max Lederman (1922–), Melvin Schwartz (1932–2006), and Jack Steinberger (1921–), American physicists, win the Nobel Prize for physics for their neutrino beam method and the demonstration of the doublet structure of the leptons through the discovery of the muon neutrino.

1988 A scanning-tunneling microscope produces the first clear image of molecular structure.

1988 Eric Courchesne and colleagues show that autistic children develop brain abnormalities in the womb or shortly after birth and that autism is caused by a decrease in Purkinje cells.

1988 Philip Leder (1934–) and Timothy Stewart of Harvard Medical School are granted the first U.S. patent for a genetically-altered vertebrate. This "transgenic non-human mammal"—a genetically-altered mouse—is developed by genetic engineering to be highly susceptible to breast cancer.

1988 Henry A. Erlich of the United States and colleagues develop a method for identifying an individual from the DNA in a single hair.

1988 James Whyte Black (1924–), English pharmacologist, Gertrude Bell Elion (1918–1999), American pharmacologist, and George Herbert Hitchings (1905–1998), American pharmacologist, are awarded the Nobel Prize for physiology or medicine for their discoveries of important principles for drug treatment.

1988 Johann Deisenhofer (1943–), Robert Huber (1937–), and Hartmut Michel (1948–), German biochemists, are awarded the Nobel Prize for chemistry for the determination of the 3-D structure of a photosynthetic reaction center.

1988 Michael Gurnis (1959–), Bradford Hoadley Hager, and Arthur Raefsky of the United

States develop a numerical computer model to study the two-way dynamic feedback between continental drift and mantle convection, demonstrating that congregated continents initiate upwelling in the mantle, which is followed by breakup and dispersal of the continents.

1988 National Institute of Health approves the injection of genetically-altered cells into humans.

1988 Scientists announce the synthesis of ginkgolide B, which they believe is the active principle in ginkgo herbal remedies. This chemical relieves allergies by suppressing the immune system.

1988 Rudolf Jaenisch (1942–) and colleagues announce the successful implantation of a human hereditary disease in mice. They expect to be able to better study a disease this way.

1988 Louis Kunkel (1949–), Eric P. Hoffman, and colleagues announce that sufferers from Duchenne muscular dystrophy lack the protein dystrophin. They believe it may now be possible to diagnose the disease in its earliest stages.

1989 Norman Foster Ramsey (1915–), American physicist, Hans Georg Dehmelt (1922–), American physicist, and Wolfgang Paul (1913–1993), German physicist, win the Nobel Prize for physics. Ramsey wins for the invention of the separated oscillatory fields method and its use in the hydrogen maser and other atomic clocks. Dehmelt and Paul win for their development of the ion trap technique.

1989 John Michael Bishop (1936–) and Harold Elliot Varmus (1939–), both American virologists, are awarded the Nobel Prize for physiology or medicine for their discovery of the cellular origin of retroviral oncogenes.

1989 Rocks 3.96 billion years old, from near Canada's Great Slave Lake, replace rocks from west Greenland, which are about 100 million years younger, as the world's oldest known rocks. Their age is determined through measurements of uranium and lead contents of the mineral zircon in granite rocks. This discovery supports the idea that even older rocks, an original crust, must have existed because granites are formed from preexisting rock.

1989 Seven cloned calves are born from the same embryo.

1989 Sidney Altman (1939–), Canadian-American molecular biologist, and Thomas Robert Cech (1947–), American biochemist and molecular biologist, are awarded the Nobel Prize for chemistry for their discovery of catalytic properties of RNA.

1989 DNA sequence tagged sites (STSs) are recommended as a method for correlating diverse types of DNA clones.

1989 Francis Collins (1950–) and Lap-Chee Tsui (1950–) identify the gene coding for the cystic fibrosis transmembrane conductance regulator protein (CFTR) on chromosome 7. Mutations in this gene cause cystic fibrosis.

1989 James Dewey Watson (1928–) is appointed head of the National Center for Human Genome Research. The agency was created to oversee the $3 billion budgeted for the American plan to map and sequence the entire human DNA by 2005.

1989 The journal *Science* selects polymerase chain reaction as the "Molecule of the Year."

1989 New Technology Telescope (NTT) begins basic operations at La Silla, Chile. Operated by the European Southern Observatory, it is a prototype of the new "active optics" and uses thin, computer-directed mirrors, called meniscus mirrors, which are three times as precise as conventional mirrors.

1989 Martha P. Haynes (1951–) of the United States and Riccardo Giovanelli (1946–) of Italy announce their observation of a large cloud of gas that they believe to be a galaxy in formation.

1990 Jerome Isaac Friedman (1930–) and Henry Way Kendall (1926–1999), American physicists, and Richard Edward Taylor (1929–), Canadian physicist, win the Nobel Prize for physics for their pioneering investigations concerning deep inelastic scattering

of electrons on protons and bound neutrons, which have been of essential importance for the development of the quark model in particle physics.

1990 Elias James Corey (1928–), American chemist, is awarded the Nobel Prize for chemistry for his development of the theory and methodology of organic synthesis.

1990 First patient to receive gene therapy is a four-year old girl suffering from ADA deficiency. She receives a series of intravenous infusions of her own immune cells that have been "gene-corrected" by the introduction of normal genes encoding functional human ADA.

1990 Human Genome Project begins in the United States with the selection of six institutions to do the work.

1990 Joseph Edward Murray (1919–), American surgeon, and Edward Donnall Thomas (1920–), American physician, are awarded the Nobel Prize for physiology or medicine for their discoveries concerning organ and cell transplantation in the treatment of human disease.

1990 Michael Crichton (1942–), inspired by advances in molecular biology, publishes the novel *Jurassic Park,* in which bioengineered dinosaurs roam a paleontological theme park.

1990 Research and development begin for efficient production of more stable, large-insert bacterial artificial chromosomes (BACs).

1990 Researchers at various laboratories began projects to mark gene sites on chromosome maps as sites of mRNA expression.

1990 Edouard Bard of the United States and colleagues report extending the calibration of the carbon dating scale from the traditional 8,000 to 9,000 years (which uses tree-ring records) to 30,000 years by dating corals drilled off Barbados. These new results improve the accuracy of the method based on the radioactive decay of the isotope carbon-14.

1990 Jack O. Burns and Michael J. Ledlow report that Mercury has two "hot poles." These are hot spots on the planet's equator that receive more sunlight than other parts of the surface.

1990 Astronomers begin to explore "adaptive optics," the main purpose of which is to remove the twinkling that is caused by distortion of light as it passes through the atmosphere. Success would result in a perfectly steady image.

1991 A new material called Nitromag is discovered by a team of scientists in Ireland. Belonging to the generation of permanent magnetic alloys, its composition (Nd2 Fe17 N3) is such that magnets made of this material remain useful at much higher temperatures, allowing them to be used in more severe environments.

1991 Pierre-Giles de Gennes (1932–), French physicist, wins the Nobel Prize for physics for his studies of the changes that take place in liquid crystals when the orientation of the molecules changes from a random or disordered state to an aligned or ordered state.

1991 Andrew A. Griffith, American chemist, uses an atomic force microscope to obtain extraordinarily detailed images of the electrochemical reactions involved in corrosion.

1991 Arthur J. Epstein (1945–) and Joel S. Miller (1944–), American chemists, develop the first molecular magnet that retains its magnetic properties at room temperature and above.

1991 Astronomers in England discover a new pulsar, PSR 1829–10, that suggests it could be an extrasolar planet.

1991 Erwin Neher (1944–), German physicist, and Bert Sakmann (1942–), German physician, are awarded the Nobel Prize for physiology or medicine for their work in uncovering basic cell functions.

1991 International teams working in the United States, France, and Japan lead to the pinpointing of the gene responsible for Marfan syndrome, an inherited disorder of connective tissue, characterized by tall stature and several complications.

1991 John Torny of the United States photographs the most distant star observed to

date. He obtains images of individual stars in the NGC 4571 galaxy in the Virgo cluster that are 50 million light years away.

1991 John V. Budding, American chemist, leads a group that compresses iron and hydrogen in a diamond cell, making the first observations of the chemical combination of iron and hydrogen under ultrahigh pressures to form iron hydride.

1991 *Magellan* spacecraft completes its first map of the surface of Venus. Using its penetrating syntectic aperture radar, it is able to map about 84 percent of the cloud-covered surface.

1991 Ongoing radar mapping of the planet Venus from the orbiting U.S. spacecraft *Magellan* unveils much of the planet's surface, revealing an array of striking tectonic features and confirming a dominant role for volcanic activity.

1991 Research in the United States produces evidence that drug treatment with GM-1 ganglioside initiates progress in the management of patients suffering from spinal cord injury.

1991 Researchers obtain the first evidence of medium-range structural order in glass. Using a sensitive neutron-scattering technique, they study the atomic structure of calcium silicate glass and discover calcium ions distributed in a manner similar to crystals. This discovery may lead to ways for optimizing the mechanical, optical, and other properties of glass by modifying this newly-discovered structure.

1991 Richard Robert Ernst, Swiss chemist, is awarded the Nobel Prize for chemistry for his contributions in refining the technology of nuclear magnetic resonance imaging.

1991 Several research reports reinforce the importance of regular exercise in reducing the risk of coronary heart disease.

1991 The safety of breast implants continues to be questioned, with problems such as silicon leakage, allergic reactions, and interference in the detection of breast cancer occurring in as many as 30 percent of the two million women in the United States who received implants.

1991 The sex of a mouse is changed at the embryo stage.

1991 This year is characterized by a marked increase in the number of research papers published on fullerenes. This unusual family of ball-shaped carbon molecules consists of hollow clusters of carbon atoms bonded into geodesic structures that resemble the geodesic domes popularized by the American engineer and architect R. Buckminster Fuller (1895–1983). They represent a previously unrecognized form of elemental carbon with a structure radically different from either of the two well-recognized forms. Initial research indicates that fullerenes may contribute to the advance of high-temperature superconductors.

1991 The Food and Drug Administration and National Institutes of Health report they find that mercury from amalgam teeth fillings poses no direct hazard to human health.

1991 The Food and Drug Administration announces it will speed up its process for approving drugs. This change in procedure is due to the protests of AIDS activists.

1991 The National Institutes of Health begins a new type of cancer gene therapy using genes from a natural tumor-fighting substance in cells called tumor necrosis factor (TNF).

1991 Mary-Claire King (1946–) concludes, based on her studies of the chromosomes of women in cancer-prone families, that a gene on chromosome 17 causes the inherited form of breast cancer and also increases the risk of ovarian cancer.

1991 The Genome Database, a human chromosome mapping data repository, is established.

1991 The longest and most observable solar eclipse of the century occurs. It will not be exceeded in length for another 140 years.

1991 *Galileo* spacecraft comes within 2,000 km of the asteroid Gaspra (between the orbits of Mars and Jupiter) and takes the first photograph of an asteroid that has any kind of detail. It shows that Gaspra is irregular in shape, about 20 km long and 13 km wide, and is heavily pitted with craters.

1992 Georges Charpak (1924–), French physicist, wins the Nobel Prize for Physics for devising an electronic detector that records the trajectories of subatomic particles in atom smashers.

1992 Alexander Wolszczan (1946–), American astronomer, announces what he believes to be the discovery of a planet circling a pulsar.

1992 An astonishing reemergence of pulmonary tuberculosis (TB) occurs in the large cities of the United States and Europe.

1992 David Jewitt (1958–) and Jane X. Luu (1963–), American astronomers, discover an object that may be the first of a new class of objects at the edge of the solar system, beyond the orbits of Pluto and Neptune. Called a "planetismal," it is about 124.3 feet (200 km) in diameter and lies 42 astronomical units from the sun

1992 Discovery of the oldest Earth's crust is made by R. Maas and colleagues in western Australia. It is dated between 3.9 and 4.2 billion years.

1992 Edmond H. Fischer (1920–) and Edwin G. Krebs (1918–), both American biochemists, are awarded the Nobel Prize for physiology or medicine for their discovery in the 1950s of a cellular regulatory mechanism used to control a variety of metabolic processes.

1992 James Dewey Watson (1928–), American biochemist and leader of the Human Genome Project, resigns. Many believe he is leaving the project—the goal of which is to locate all the genes that the DNA comprises within a human cell's 46 chromosomes and to determine the precise order of the 3 billion gene subparts or nucleotides that form the genetic code—because of differences on the issue of gene patenting.

1992 Researchers at Harvard Medical School investigate 15 male schizophrenics using magnetic resonance imaging (MRI) and find that compared with 15 normal control subjects, their patients' had significant reductions (13–19%) in the volume of gray matter in three specific regions of the left temporal lobe of the brain.

1992 Researchers in the United States report the production of the first solid compound of the noble gas helium. A solid is formed when helium and nitrogen are mixed together and subjected to about 77,000 times normal pressure.

1992 Rudolph A. Marcus (1923–), Canadian-American chemist, is awarded the Nobel Prize for chemistry for his mathematical analysis of the cause and effect of electrons jumping from one molecular to another.

1992 The era of animal-to-human transplants begins with the transplantation of a baboon's liver into a man whose liver had been almost destroyed by hepatitis B. The patient dies 71 days after surgery of a brain aneurysm.

1992 The National Geologic Mapping Act becomes law in the United States. This act will expedite production of a geologic map database for the United States that can be applied to land use management assessment, conservation of natural resources, groundwater management, and environmental protection. It is expected to reverse the drastic curtailment in geologic map production that has taken place since the 1970s.

1992 WHO (World Health Organization) predicts that by the year 2000, 30 to 40 million people will be infected with the AIDS-causing HIV. A Harvard University group argues that the number could reach more than 100 million.

1992 American and British scientists describe a technique for testing embryos *in vitro* for genetic abnormalities such as cystic fibrosis and hemophilia.

1992 J. Craig Venter (1946–) establishes The Institute for Genomic Research (TIGR) in Rockville, MD. TIGR later sequenced *Haemophilus influenzae* and many other bacterial genomes.

1992 Francis S. Collins (1950–) replaces James Dewey Watson (1928–) as head of the National Center for Human Genome Research at the National Institutes of Health. Watson had clashed with J. Craig Venter, then at NIH, over the patenting

of DNA fragments known as "expressed sequence tags."

1992 Harry F. Noller (1939–) demonstrates that RNA plays a greater role in protein synthesis than had been assumed.

1992 Low-resolution genetic linkage maps of the entire human genome are published.

1992 Guidelines for data release and resource sharing related to the Human Genome Project are announced by the United States Department of Energy and National Institutes of Health.

1992 The Food and Drug Administration severely restricts the use of silcone-gel filled breast implants. Earlier in the year, it became known that the major manufacturer of the implants, Dow Corning Corp., had concealed some information on implant difficulties.

1992 George Smoot (1945–), American astronomer, announces that the Cosmic Background Explorer (CBE) satellite has detected small fluctuations in the microwave background radiation. He interprets what he calls "the handwriting of God" as evidence of the big bang.

1992 Observations with the U.S. Gamma Ray Observatory (GRO) satellite, the first true gamma-ray telescope launched into orbit, reveal for the first time the presence of fast neutrons produced in solar flares.

1992 The Earth Summit concludes in Rio de Janeiro, Brazil. Attended by most of the countries of the world, the summit produces a number of pacts to help the environment. One of these is geared toward protecting the world's plant, animal, and even microbial species.

1993 Joseph Hooten Taylor, Jr., (1941–) and Russell Alan Hulse (1950–), American astrophysicists, win the Nobel Prize for Physics for their discovery of a new type of pulsar, termed a binary pulsar, that has opened up new possibilities for the study of gravitation.

1993 Researchers state that the results of new observatories indicate that the stars, dust, and other observable matter in space represent less than 10% of all the mass in the universe. These results support a long-held belief that the universe holds a great deal of undetected "dark matter."

1993 Jacob Israelachvili (1944–), American chemist, and co-workers report the first experimental observation of a state of ultra-low friction. They observe this phenomenon during studies of the so-called stick-slip motion of specially treated mica surfaces.

1993 Jeffrey S. Moore (1962–) and Zhifu Xu (1962–), American chemists, first synthesize the largest all-hydrogen molecule ever made.

1993 Joseph B. Lambert (1940–), American chemist, heads a team that reports success in making a stable silicon (Si) cation, a positively charged form of the element that is attached to other atoms by three bonds. This may have important applications as a catalyst in speeding up polymerization reactions used in making adhesives, lubricants, and other silicon products.

1993 Palm-size computers called personal digital assistants (PDAs) are introduced by several firms. These hand-held PC's have no keyboard, and users write directly on its plastic screen with a special pen. The software converts the handwriting to type.

1993 Researchers in England announce that studies indicate that babies who sleep in prone positions are at increased risk of SIDS (Sudden Infant Death Syndrome) and suggest that infants be placed on their backs or sides.

1993 Researchers in France announce that they have succeeded in constructing the first rough map of all the human chromosomes.

1993 Richard Roberts (1943–) and Phillip Sharp (1944–), both American molecular biologists, are awarded the Nobel Prize for physiology or medicine for their independent discovery that genes are often split (that the genetic instructions contained in DNA and used by the living cell to make proteins can be discontinuous).

1993 Software companies introduce programs making the Internet easier to use, and several online information services open

gateways into this "network of networks," making its popularity explode.

1993 Swiss researchers report making a mercury-containing ceramic material that starts to become superconducting (losing all resistance to the flow of electricity) when cooled to about 133° K.

1993 Teams of researchers in the United States and Europe discover the gene for Huntington's disease. They find a genetic "mistake" on chromosome 4 that gives affected individuals this hereditary neurological affliction.

1993 The first genetically-altered food for human consumption, the Flavr Savr tomato, awaits approval by the Food and Drug Administration (FDA).

1993 The National Academy of Sciences publishes the report *Solid-Earth Sciences and Society*, which recommends priorities for future research in the field while delineating the scientific challenges facing modern society. The report recommends viewing Earth as an integrated, dynamic system rather than as a collection of isolated components divided up among different disciplines.

1993 Virgil Sharpton of the United States and colleagues estimate the scar impact crater at Chicxulub in Mexico's Yucatan Peninsula to be about 186.4 miles (300 km) in diameter, nearly twice as wide as the previous estimate. If correct, this would reinforce arguments that the crash of an extraterrestrial object 65 million years ago was in some way responsible for the mass extinction of dinosaurs and many other creatures.

1993 The Internet browser Mosaic is released by Marc Andreesen (1971–), Eric Bina (1964–), and Jim H. Clark (1944–); it is instantly and widely popular.

1993 Intel releases the first of its Pentium chips; it contains more than twice the number of transistors than its previous release.

1993 After analyzing the family trees of gay men and the DNA of pairs of homosexual brothers, biochemists at the United States National Cancer Institute report that at least one gene related to homosexuality resides on the X chromosome, which is inherited from the mother.

1993 Flavr Savr tomatoes, genetically engineered for longer shelf life, are marketed.

1993 French Gépnéthon makes its mega-YACs available to the genome community.

1993 IOM releases the U.S. HGP-funded report "Assessing Genetic Risks."

1993 Kary Mullis (1944–) and Michael Smith (1932–2000) are awarded the Nobel Prize in chemistry. Mullis is honored for the discovery of polymerase chain reaction. Smith is chosen for his fundamental contributions to the establishment of oligonucleotide-based, site-directed mutagenesis.

1993 Scientists identify p53, a tumor suppressor gene, as a critical factor preventing uncontrolled cell growth. The gene also performs a variety of functions ensuring cell health.

1993 The Gene Recognition and Analysis Internet Link (GRAIL) sequence-interpretation service provides Internet access at Oak Ridge National Laboratory, a Department of Energy Laboratory (ORNL).

1993 The international Integrated Molecular Analysis of Gene Expression (IMAGE) Consortium is established to coordinate efficient mapping and sequencing of gene-representing cDNAs (complementary DNAs).

1993 The Lawrence Berkeley National Laboratory (LBNL), a Department of Energy Laboratory, implements a novel transposon-mediated chromosome-sequencing system.

1993 George Washington University researchers clone human embryos and nurture them in a Petri dish for several days. The project provokes protests from ethicists, politicians, and critics of genetic engineering.

1993 Hanta virus emerges in the United States in a 1993 outbreak on a "Four Corners" (the juncture of Utah, Colorado, New Mexico, Arizona) area Native American Reservation. The resulting Hanta pulmonary syndrome (HPS) has a 43% mortality rate.

1993 The American Heart Association confirms that taking aspirin can prevent some cardiovascular problems and treat others.

1993 David Jewitt (1958–) and Jane X. Luu (1963–), American astronomers, discover five more objects just outside Neptune's orbit. They may be comets that are moving toward the sun, or they may be asteroids permanently located near Neptune.

1993 The Food and Drug Administration (FDA) approves bovine somatropin (BST), a genetically-engineered synthetic hormone that increases the amount of milk given by dairy cows.

1993 American researchers announce that they have isolated a gene in an extremely common type of colon cancer, hereditary nonpolyposis colorectal cancer. They predict a test will soon be available.

1994 Biologists discover that both vertebrates and invertebrates share certain developmental genes.

1994 Sequencing by hybridization (SBH) technologies from Argonne National Laboratory (ANL), a Department of Energy Laboratory, is commercialized.

1994 The Genetic Privacy Act, the first United States Human Genome Project legislative product, proposes regulation of the collection, analysis, storage, and use of DNA samples and genetic information obtained from them. These rules are endorsed by the ELSI Working Group.

1994 The Department of Energy announces the establishment of the Microbial Genome Project as a spin-off of the Human Genome Project.

1994 Geneticists determine that DNA repair enzymes perform several vital functions, including preserving genetic information and protecting the cell from cancer.

1994 The 5-year goal for genetic-mapping is achieved one year ahead of schedule.

1994 The Human Genome Project Information Web site is made available to researchers and the public.

1995 A physical genome map with more than 15,000 STS markers published.

1994 International team composed of Kevin O. Pope, American geologist, Kevin H. Baines (1954–), American atmospheric physicist, Adriana C. Ocampo, American planetary geologist, and Boris A. Ivanov of Russia, offer a new hypothesis explaining how the mass extinctions by asteroid impact may have come about 65 million years ago. They find that the impact site was unusually rich in sulfur, and the vaporization of more than 100 billion tons of it may have filled the atmosphere with life-killing sulfur dioxide and sulfuric acid for decades.

1975 First detections of any extra-solar system objects in the extreme ultraviolet (EUV) region (wavelengths from 100 to 1000 Angstroms or photon energies from 0.012 to 0.12 keV), namely the hot white dwarf stars Feige 24 and HZ 43, by the Apollo-Soyuz EUV Telescope.

1995 Edward B. Lewis (1918–2004), Christiane Nüsslein-Volhard (1942–), and Eric F. Wieschaus (1947–), developmental biologists, share the Nobel Prize in physiology or medicine for work that leads to the discovery of a family of genes later named "homeotic selector genes." These genes play a critical role in the organization of gene expression during development.

1995 Former football player O.J. Simpson is found not guilty in a high-profile double-murder trial in which prosecutors unsuccessfully attempt to win a conviction based, at least in part, on evidence from PCR and DNA fingerprinting techniques.

1995 LANL and LLNL announce the completion of high-resolution physical maps of chromosome 16 and chromosome 19.

1995 Moderate-resolution maps of chromosomes 3, 11, 12, and 22 maps are published.

1995 The sequence of *Mycoplasma genitalium*, which is generally regarded as the smallest known bacterium, is completed. *Mycoplasma genitalium* is considered a model of the minimum number of genes needed for independent existence.

1995 Peter Funch (1965–) and Reinhardt Moberg Kristensen create a new phylum, Cycliophora, for a novel invertebrate called *Symbion pandora*, which is found living in the mouths of Norwegian lobsters.

1995 Researchers at Duke University Medical Center report that they have transplanted

hearts from genetically altered pigs into baboons. All three transgenic pig hearts survive at least a few hours, suggesting that xenotransplants (cross-species organ transplantation) might be possible.

1995 Combinatorial chemistry, a technique that quickly surveys huge numbers of chemical combinations in order to select the most desirable molecular configurations, attracts the attention of chemical companies. Scientists predict the possibility of creating numerous new chemicals to serve the needs of industrial and pharmaceutical development.

1995 The National Household Survey on Drug Abuse finds inhalants to be the second most commonly abused illicit drug by American youth ages 12 years to 17 years, after marijuana.

1995 The Food and Drug Administration (FDA) declares tobacco cigarettes and cigars to be drug delivery devices and proposes extensive additional restrictions on sales and advertising to minors.

1995 In June, while Comprehensive Nuclear Test Ban Treaty (CTBT) negotiations are still under way, France announces that it will resume nuclear testing.

1995 Religious leaders and biotechnology critics protest the patenting of plants, animals, and human body parts.

1995 Michel Mayor (1942–) and Didier Queloz (1965–) identify the first extra-solar planet, a Jupiter-like planet orbiting an ordinary star.

1995 Paul Crutzen (1933–), Dutch meteorologist, Mario Molina (1943–), Mexican American chemist, and R. Sherwood Rowland (1927–), American atmospheric chemist, receive the Nobel Prize in chemistry for their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone.

1995 Public awareness of potential use of chemical or biological weapons by terrorist groups increases after Aum Shinrikyo, a Japanese cult, releases sarin gas in a Tokyo subway attack, killing a dozen people and sending thousands to hospitals.

1995 The Programme Against African Trypanosomiasis (PAAT) is created to quell the re-emerging parasitic disease.

1995 The National Library of Medicine unveils the "Visible Human," a digital image library of volumetric data representing complete, normal adult male and female anatomy.

1995 The genome of the bacterium *Haemophilus influenzae* is sequenced.

1995 The Food and Drug Administration approves the varicella-zoster vaccine developed by Merck for vaccinations of persons 12 months of age and older.

1995 Space shuttle *Atlantis* (STS-71) docks with the Russian space station Mir. It is the second joint U.S.-Russian mission, and the 100th U.S. manned mission.

1996 The Food and Drug Administration approves the antidepressant buproprion (Zyban) and a nicotine nasal spray for the treatment of nicotine dependence.

1996 Researchers find that abuse and violence can alter a child's brain chemistry, placing him or her at risk for various problems, including drug abuse, cognitive disabilities, and mental illness, later in life.

1996 United States Comprehensive Methamphetamine Control Act increases penalties for the manufacture, distribution, and possession of methamphetamines, as well as the reagents and chemicals needed to make it.

1996 International participants in the genome project meet in Bermuda and agree to formalize the conditions of data access. The agreement, known as the "Bermuda Principles," calls for the release of sequence data into public databases within 24 hours.

1996 The Health Care Portability and Accountability Act incorporates provisions to prohibit the use of genetic information in certain health-insurance eligibility decisions. The Department of Health and Human Services was charged with the enforcement of health-information privacy provisions.

1996 World chess champion Garry Kasparov, able to compute the ramifications of 2–3 chess moves per second, loses a chess game to IBM's Deep Blue computer, able to

compute the ramifications of 200 million moves per second. Kasparov eventually won the 6-game match.

1996 After operating on the surface of Mars three times longer than planned and returning a large amount of information about the red planet, the *Pathfinder* lander—officially renamed the Sagan Memorial Station after landing in honor of American scientist Carl Sagan (1934–1996)—finally became inactive in November 1997.

1996 Astronomers find evidence of many isolated, dim brown dwarfs, lacking sufficient mass to start nuclear fusion. They detect light spectra from the element lithium, which quickly burns in true stars. These brown dwarfs, called "L dwarfs," are typically smaller than the sun, but much larger than even Jupiter.

1996 Biosphere 2, where human residents lived from September 26, 1991, to September 26, 1993, the longest period on record that humans have lived in an "isolated confined environment," opens to public visitors, as scientists hope to plan further research at the facility.

1996 By mid-year, 103 endangered California condors are alive at animal sanctuaries in San Diego and Los Angeles, California, up from near extinction (<30 birds) in 1978. The population recovery is sufficient to allow some birds to be introduced back into the wild.

1996 Chimpanzees found dead and infected with the Ebola virus are responsible for the initiation of Ebola outbreaks in two regions of Gabon when local residents eat infected meat from the dead chimpanzees.

1996 Combined drugs therapy for AIDS is first introduced at the eleventh World AIDS conference held in Vancouver, British Columbia, Canada.

1996 Red tide of planktonic algae kills 149 endangered manatees (*Trichechus manatus latirostris*) in the coastal waters of Florida.

1996 The Department of Health and Human Services' Centers for Disease Control and Prevention (CDC) finds that nine out of 10 non-smoking Americans are regularly exposed to environmental tobacco smoke (ETS), also known as second-hand smoke. A study by the American Heart Association the following year reports that women regularly exposed to ETS have a 91% greater risk of heart attack, and those exposed occasionally a 58% greater risk—rates that are believed to apply equally to men.

1996 The population of endangered black-footed ferrets rises from near extinction to more than 500 in captivity, along with several hundred black-footed ferrets that are returned to the wild, mostly in Wyoming, Utah, and Colorado.

1996 Researchers at Lawrence Livermore National Laboratory convert hydrogen into metallic hydrogen, the lightest metal in the universe.

1996 Astronomers unveil the Hubble Deep Field, a narrow "keyhole" view stretching to the visible horizon of the universe. Analysis of the images spawns fresh insights into the birth and evolution of galaxies.

1996 Based upon observations of comet Hyakutake, astronomers suggest that some comets contain frozen clouds of gas and dust containing particles that originally formed the universe.

1996 Environmental scientists observe the first measured decline of ozone-depleting compounds in the atmosphere since measurements began.

1996 Geneticists determine that the first animals on Earth likely emerged more than a billion years ago, much earlier than previously suspected.

1996 Geologists conduct seismic studies that reveal that Earth's inner core is spinning faster than the rest of the planet.

1996 Geologists generate computer models of Earth's interior that offer an explanation of why tectonic plates are so large.

1996 Immunologists determine that cells shed by an unborn baby are able to survive up to 27 years in its mother's blood and are possibly linked with some autoimmune diseases occurring later in the mother's life.

1996 North American honeybee populations experience a pandemic of parasites that

becomes part of a larger threat to natural pollinators.

1996 Olestra, a calorie-free fat substitute, is approved by the FDA for use in processed foods, despite reports that its ingestion can cause gastrointestinal side effects.

1996 Paleontologists discover scales belonging to the earliest known sharks.

1996 Physicists obtain the first direct images of a subatomic particle called a Bose-Einstein condensate and observe how they vibrate when excited.

1996 Physicists use lasers and an electromagnetic trap to oscillate a single beryllium atom into a state of matter that appears in two positions at the same time.

1996 Pollution limits are tightened by the Environmental Protection Agency, especially for outdoor respirable dust-sized pollutants, whose increased concentrations are blamed for many deaths from respiratory and heart disease.

1996 Radiation-induced mutations are observed in children of some survivors of the 1986 Chernobyl nuclear accident.

1996 Remains of former Russian Czar Nicholas II are authenticated by genetic analysis.

1996 Researchers pinpoint the location of Lake Vostok in Antarctica, one of Earth's largest, deepest bodies of freshwater.

1996 Researchers report firm evidence that a black hole lies at the heart of our galaxy.

1996 Scientists announce that antioxidants, compounds found in dark beer, some fruit juices, and chocolate, may lower the risk of heart disease and cancer.

1996 Scientists discover that mutations in proteins on the surface of cells enable some people to be resistant to HIV infection, or inhibit the progression of AIDS symptoms.

1996 Scientists find a gene with cancer prevention abilities is inhibited by the effects of cigarette smoking.

1996 Scientists identify the genes that cause diabetes, one type of cardiac abnormality, pancreatic cancer, a form of epilepsy, and a premature aging syndrome.

1996 Scientists learn that bats can harbor the Ebola virus.

1996 Scientists report that the musical ability of perfect pitch appears to be inherited.

1996 Study of 3.2–billion-year-old rocks reveals that Earth's magnetic field matured early in its history.

1996 Study of an ancient Eurasian pottery jar reveals that the practice of wine-making is at least 7,000 years old.

1996 The link between dinosaurs and birds is strengthened when Chinese scientists find dinosaur fossils that reveal the animal was covered in featherlike structures.

1996 Variant Creutzfeldt-Jacob's disease, the human version of mad cow disease, is reported in the United Kingdom.

1996 Researchers C. Cheng and L. Olson demonstrate that the spinal cord can be regenerated in adult rats. Experimenting on rats with a severed spinal cord, Cheng and Olson use peripheral nerves to connect white matter and gray matter.

1996 Scientists discover a link between apoptosis (cellular suicide, a natural process whereby the body eliminates useless cells) gone awry and several neurodegenerative conditions, including Alzheimer's disease.

1996 Jagarlapudi Sarma, of the Indian Institute of Chemical Technology, in Hyderabad, India, determines that organic molecules tend to contain even numbers of atoms. Chemists hope that Sarma's discovery may lead to new insights on the nature of chemical bonding.

1996 Scientists discover a new molecular form of carbon. Although initially viewed with skepticism by the scientific community, the 60-atom molecules named fullerenes have numerous applications in industry.

1996 Chris Paszty and co-workers successfully employ genetic engineering techniques to create mice with sickle-cell anemia, a serious human blood disorder.

1996 Researchers report important progress in understanding BRCA1 and BRCA2, the genes responsible for some types of breast cancer.

1996 The sequence of the *Methanococcus jannaschii* genome provides further evidence of the existence of a third major branch

of life on earth, the archaea. This genome was the first ever sequenced by the whole genome shotgun method.

1996 The Wellcome Trust sponsors a large-scale sequencing strategy meeting for international coordination of human genome sequencing.

1996 Quark-gluon plasma, a form of matter that was created in the first few microseconds following the big bang, is created as a result of collisions between lead nuclei.

1996 The genome of baker's yeast, *Saccharomyces cerevisiae*, is sequenced by an international consortium of scientists. The short generation span and ease of genetic manipulation of the yeast provide a suitable system to study basic biological processes that are relevant for many other higher eukaryotes, including humans.

1996 The South Carolina Supreme Court decides in favor of the Medical University of South Carolina (MUSC) policy to secretly test pregnant patients for cocaine use. Subsequently, in 200I, the United States Supreme Court rules that based on the Fourth Amendment, hospitals cannot test pregnant women for drugs without their consent and then inform the police.

1996 The United States Drug-Induced Rape Prevention and Punishment Act makes it a felony to give an unsuspecting person a drug with the intent of committing violence, including rape. The law also imposes penalties of large fines and up to 20 years in prison for importing or distributing more than one gram of date rape drugs.

1996 Dolphins and sea lions are used to protect the waters off of San Diego, California, during the Republican Party Convention.

1996 H5NI strain Avian flu is first detected in a goose in Guangdong province, China.

1996 Scientists report evidence that individuals with certain genetic mutations (two mutant copies of the CC-CLR-5 gene) are generally resistant to HIV infection.

1996 SigF, a gene in the tuberculosis bacterium, is found to enable the bacterium to enter a dormant stage.

1996 Publication date of the discovery of the first, generally credited isolated (non-binary) neutron star based on ROSAT (Röntgensatellit; a German x-ray satellite telescope) observations.

1996 A report of x-ray and EUV emission from Comet C/1996 B2 (Hyakutake) is the first-ever report of either x rays or EUV emission from a comet.

1996 Chinese *Homo erectus* fossils collectively known as Peking Man are dated to at least 400,000 years ago.

1997 The Food and Drug Administration (FDA) reports and investigates correlation of heart valve disease in patients using phen-fen drug combinations for weight loss. There are similar reports for patients using only dexfenluramine or fenfluramine. The FDA notes that the combination phen-fen treatment had not received FDA approval.

1997 Institute of Medicine (IOM), a branch of the National Academy of Sciences, publishes the report *Marijuana: Assessing the Science Base*, which concludes that cannabinoids show significant promise as analgesics, appetite stimulants, and anti-emetics, and that further research into producing these medicines is warranted.

1997 Rohypnol, the sedative-hypnotic drug often associated "date rape," is banned in the United States.

1997 Ian Wilmut (I944–) of the Roslin Institute in Edinburgh, Scotland, announces the birth of a lamb called Dolly, the first mammal cloned from an adult cell (a cell in a pregnant ewe's mammary gland).

1997 Astronomers discover a fountain of hot gas and antimatter shooting 3,500 light years out of the nucleus of the Milky Way.

1997 Britain bans specified risk material containing beef matter from animal feed, cosmetics, and pharmaceutical preparations, and introduces new rules on beef labeling and tracing procedures, in an effort to contain the spread of bovine spongiform encephalopathy (BSE) and the human form of mad cow disease.

1997 Climatologists observe that 1997 is an unusually hot year in many parts of the

world, but lack sufficient evidence to conclude whether it is part of a general trend towards warmer weather or a single variation that will not appear again for some time.

1997 Clinical studies reported in the journal *Circulation*, published by the American Heart Association, find exaggerated response to mental stress can produce the same degree of atherosclerosis risk as do smoking and high cholesterol, thereby increasing the risk of heart disease and stroke.

1997 Fred Vine (1939–) at Cambridge University uses magnetometer readings previously collected to correlate the paired bands of varying magnetism and anomalies located on either side of divergent boundaries. Data gathered confirms previous scientific assertions regarding seafloor spreading.

1997 Hubble Space Telescope detects the (then) brightest star ever seen. Discovered at the core of our own galaxy and named the Pistol Star, it has the energy of 10 million suns and would fill the distance of Earth's orbit around the sun.

1997 Mountaintop mining, a process in which the overburden of earth atop the harvested coal is used to fill in adjacent valleys, comes into widespread use in Appalachian coal fields, despite the potential for negative environmental impact, following the passage of the Surface Mining Control and Reclamation Act by the United States Congress.

1997 NASA scientists announce evidence that the Murchison meteorite contains microfossils that resemble microorganisms. The microfossils were discovered in fresh breaks of meteorite material and spark intense scientific study and debate.

1997 Proteomics, a science that investigates the global changes of proteins in cells and tissues in response to a stimulus and protein-protein interactions, becomes a popular research avenue, holding much greater importance than scientists initially suspected.

1997 Remains from Neanderthals, thought to have disappeared about 35,000 years ago, are found in Croatia, and are dated to 28,000 years ago.

1997 Researchers from the University of Michigan release a detailed projection of the four phases of the universe, including the ultimate end in the Dark Era, some 10^{100} years hence.

1997 The antihistamines Seldane and Seldane-D are taken off the market due to concerns that the active ingredient, terfenadine, triggers life-threatening heart rhythm problems when taken with certain drugs.

1997 The *Journal of the National Cancer Institute* states that nicotine addiction rates are higher than for alcohol or cocaine, and that of all people trying only one cigarette, 33–50% will ultimately become addicted.

1997 The Kyoto Agreement is proposed to the nations of the world, recognizing global warming patterns and calling on nations to cut carbon emissions, reduce levels of so-called "greenhouse gases" (methane, carbon dioxide, and nitrous oxide), and use existing technologies to improve energy efficiency.

1997 The National Human Genome Research Institute (NHGRI) is recognized as a collaborative institute; physical maps of chromosomes X and 7 are announced.

1997 A new strain of the flu virus hosted by chickens surfaces in China, killing two people.

1997 A record El Nĩno develops in the Pacific Ocean, altering the typical hurricane pattern and causing severe drought in Australia, Northern Africa, and Southeast Asia.

1997 Analysis of seafloor sediments suggests that interplanetary dust may have triggered the ice ages.

1997 Biologists find a molecular component of the mammalian circadian cycle (biological clock) that influences daily patterns of activities.

1997 Conservation groups launch efforts to preserve rare breeds of livestock and to build public awareness of the genetic traits that could be lost if these animals become extinct.

1997 Debate over xenotransplantation (cross-species transplantation) renews after

scientists learn that some pig viruses can infect human cells.

1997 The Food and Drug Administration revises its recommendations for vitamin intake, replacing the suggested daily minimums (RDAs), with dietary reference intakes (DRIs), intended to support optimum health.

1997 Findings showing that inflammation plays a key role in the development of heart disease force cardiologists to overhaul traditional thinking about atherosclerosis formation.

1997 Genetic analysis of wheat indicates that it was first domesticated in the mountains of southern Turkey.

1997 Low calorie diets are shown to slow metabolism and lead to a longer lifespan in primates.

1997 New evidence indicates a genetic basis for schizophrenia.

1997 New names for the heavy elements numbered 104 to 109 are adopted (rutherfordium, dubnium, seaborgium, bohrium, hassium, mietnerium).

1997 Plastic biofilms are developed that prevent bacteria from binding to them, helping to prevent the potentially deadly infections that can develop around medical implants.

1997 Satellite data suggest that the sun's radiation is growing in intensity.

1997 Scientists discover a body beyond Neptune's orbit that hints at a new group of frozen objects at the edges of the solar system.

1997 Scientists in Madagascar discover a tree, previously thought extinct, that is central to the evolution of flowering plants.

1997 Scientists use antibodies to deliver radioactive atoms directly to cancerous cells, killing the cancer cells but causing little damage to healthy tissue.

1997 Some strains of the bacterium *Staphylococcus aureus* show resistance to vancomycin, the only remaining antibiotic effective against it.

1997 Stanley B. Prusiner (1942–) wins the Nobel Prize in physiology or medicine for his studies of prions, a new infectious agent composed of malformed proteins and implicated in neurological disorders such as the human form of mad cow disease.

1997 Studies of x-ray-emitting gas around neutron stars and suspected black holes suggests that spinning bodies drag space-time along with them.

1997 Study of lung tissue from victims of the 1918 flu pandemic reveals some genes of the deadly virus.

1997 The Food and Drug Administration (FDA) permits manufacturers of low-fat, oat-rich cereals found to lower cholesterol in the blood to advertise the claim.

1997 The largest (then) known prime number, 895,932 digits long, is found by a participant in the Great Internet Mersenne Prime Search.

1997 The number pi is computed to a record 51 billion decimal digits.

1997 A pyroclastic flow bursts from the Sourfriere Hills volcano on the island of Montserrat in the Caribbean. The volcanic eruptions devastate the island.

1997 A study argues that women who eat wholegrain foods and other rich sources of phytoestrogens are found less likely to develop breast cancer.

1997 Mickey Selzer, neurologist at the University of Pennsylvania, and coworkers, find that in lampreys, which have a remarkable ability to regenerate a severed spinal cord, neurofilament messenger RNA effects the regeneration process by literally pushing the growing axons and moving them forward.

1997 Researchers identify a gene that plays a crucial role in establishing normal left–right configuration during organ development.

1997 Scientists announce that they have cloned rhesus monkeys from early stage embryos, using nuclear transfer methods.

1997 While performing a cloning experiment, Christof Niehrs (1962–), a researcher at the German Center for Cancer Research, identifies a protein responsible for the creation of the head in a frog embryo.

1997 After years of experimenting, scientists determine that 106 is the correct atomic

number of seaborgium, the heavy element named after chemist Glenn Theodore Seaborg (1912–1999).

1997 Researcher Fred Regnier, of Purdue University, develops a computer chip containing miniature chemical laboratories capable of performing complex analyses and experiments, heralding an era of inexpensive and swift chemical research.

1997 IBM computer Deep Blue becomes the first machine to beat a reigning World Chess Champion (Gary Kasparov), in a rematch of the previous year's games.

1997 Researchers report progress in using the study of genetic mutations in humans and mice to decipher the molecular signals that lead undeveloped neurons from inside the brain to their final position in the cerebral cortex.

1997 Researchers find evidence for the existence of an exotic meson which combines quarks and gluons, confirming the standard particle and force theory.

1997 Experiments at the Fermi National Accelerator Laboratory provide the first direct evidence of the existence of the subatomic particle tau neutrino.

1997 Joseph Kirschvink presents evidence that the Earth's axis of rotation moved 90 degrees, in a geologically brief amount of time at the beginning of the Cambrian era, to what had formerly been the equator.

1997 The *Journal of the American Medical Association* (JAMA) publishes a study indicating ginkgo dietary supplements might be useful in treating Alzheimer's disease, sparking additional research interest.

1997 Oregon voters approve The Death with Dignity Act, allowing terminally ill people to receive prescriptions for lethal dosages of drugs to end their lives.

1997 Julia Butterfield Hill climbs a 180-foot (55-m) redwood tree in California to protest the logging of the surrounding forest as well as to protect the tree. Hill removes herself from the tree in 1999 after she negotiates a deal to save the tree and an additional three acres of the forest.

1997 First outbreak of H5N1 strain Avian flu in humans is documented when six of 18 people infected die from infection. In response, the entire poultry population of Hong Kong is culled (killed).

1997 The complete genome sequence of the common *E. coli* bacterium is determined. This accomplishment gives researchers a powerful new tool for understanding fundamental questions of biological evolution and function.

1997 Vice President Al Gore performes an "inaugural search," opening up free access on the Internet to the National Library of Medicine's MEDLINE, a one-stop repository of scientific and medical journals and one of the first free searchable online mega-databases.

1998 Nicotine inhaler (Nicotrol Inhaler) is introduced.

1998 Sibutramine (Meridia) is introduced as a weight-loss drug. Sibutramine inhibits the reuptake of the brain chemicals norepinephrine, dopamine, and serotonin, but does not promote monoamine release like the amphetamines.

1998 Craig Venter (1946–) forms a company (later named Celera), and predicts that the company will decode the entire human genome within three years. Celera plans to use a "whole genome shotgun" method, which would assemble the genome without using maps. Venter initially asserts that his company will not follow the Bermuda principles concerning data release.

1998 DNA fingerprinting is used to identify the remains of some members of the Russian Imperial Romanov family.

1998 A new genetically engineered rabies vaccine costs a fraction of the regular vaccine, making the rabies vaccine more available to people in developing countries, where over 40,000 still die every year from the disease.

1998 Astronomers discover a protoplanet (planet in the process of formation) apparently in the midst of being ejected from its star system. Infrared images from the Hubble Space Telescope show a pinpoint object

with a 130 billion-mile-long (209.2 billion-km-long) filamentary structure trailing behind it toward a pair of binary stars.

1998 Scientists working in Japan find evidence that at least some of the three types of neutrinos have a small, but nonzero, mass.

1998 The Italian Beppo-SAX registers a gamma ray burst that is determined to be larger than any other cosmic explosion yet detected, except for the big bang.

1998 The planet Pluto resumes its usual place as the sun's most distant known planet, after Neptune's orbit was more distant from 1995 to 1998.

1998 Two independent chemical studies give evidence that at least some signs of the microorganisms found in the ALH84001 meteorite from Mars are of contamination from Earth.

1998 Using data from the Cosmic Background Explorer (COBE), astronomers discover a background infrared glow across the sky. Radiated by dust that absorbs heat from all the stars that have ever existed, the background glow puts a limit on the total amount of energy released by all the stars in the universe.

1998 A tsunami strikes Papua New Guinea after a 7.1 magnitude earthquake occurs in northern New Guinea near the coast.

1998 An 8.1 magnitude earthquake occurs off the southeast coast of Antarctica near the Balleny Island region.

1998 Scientists pinpoint the first known case of AIDS from a blood sample taken from an African man who died from an unknown disease in 1959.

1998 The explosive growth of the World Wide Web spurs computer scientists to improve search techniques and develop methods to model Internet traffic.

1998 The smallest possible drop of water is found to contain six water molecules.

1998 Scientists find that an adult human's brain can, with certain stimuli, replace cells. This discovery heralds potential breakthroughs in neurology.

1998 Researcher Katsuya Shimizu, of Osaka University, and coworkers, discover that oxygen acts as a superconductor if chilled to a temperature close to absolute zero.

1998 Theoretical chemist John A. Pople (1925-) and physicist Walter Kohn (1923-) receive the Nobel Prize in chemistry for pioneering work in computational chemistry. Pople developed computational methods in quantum chemistry and Kohn developed density-functional theory.

1998 A telomere sequence having implications for aging and cancer research is identified at LANL.

1998 British and American scientists complete the genetic map of the nematode, *Caenorabditis elegans*. The genetic map, showing the 97 million genetic letters, in correct sequence, derived from the worm's 19,900 genes, was the first completed genome of an animal.

1998 DNA testing indicates that Thomas Jefferson probably had at least one child with Sally Hemings, one of his slaves.

1998 Dolly, the first cloned sheep, gives birth to a lamb that has been conceived by a natural mating with a Welsh Mountain ram. Researches said the birth of Bonnie proves that Dolly was a fully normal and healthy animal.

1998 Scientists at Japan's Kinki University announce the cloning of eight identical calves using cells from an adult cow.

1998 The Department of Energy and National Institutes of Health announces a new five-year plan for the Human Genome Project, which predicts that the project will be completed by 2003.

1998 Two research teams succeed in growing embryonic stem cells.

1998 University of Hawaii scientists, improving Ian Wilmut's technique, clone a mouse from cumulus cells. The process is repeated for three generations, yielding over fifty cloned mice by the end of July.

1998 The genome of the *Mycobacterium tuberculosis* bacterium is sequenced.

1998 The Laser Interferometer Gravitational Observatory (LIGO) project begins construction, with goals of attempting to directly verify the existence of gravitational waves and opening new ways to observe

and measure the composition and evolution of the universe.

1998 The use of Ritalin in children is re-evaluated, as researchers determine that one half of every dose of Ritalin, the widely prescribed drug for ADHD (attention-deficit-hyperactivity disorder), has no therapeutic effect. Ritalin, like many drugs, consists of two molecular forms of a compound, each structurally mirroring the other. Researchers find that only one form of the pair is therapeutically significant, suggesting the desirability of using the drug in a purer form.

1998 The tobacco industry settles lengthy lawsuits by making a historic agreement with the States' Attorneys General called the Master Settlement Agreement (MSA). In exchange for protection from further lawsuits, the industry agrees to additional advertising restrictions and to reimburse the states billions of dollars over 25 years to pay for smoking-related illnesses.

1998 United States Drug Free Communities Act offers federal money to communities to help educate citizens on the dangers of methamphetamine use and production.

1998 DNA analyses of semen stains on a dress worn by Monica Lewinsky are found to match DNA from a blood sample taken from President Bill Clinton.

1998 Researchers report that a strain of laboratory mice can regenerate tissue in their ears, closing holes that scientists had created for identification purposes. This discovery reopens the discussion on possible regeneration in humans.

1998 Scientists in Korea claim to have cloned human cells.

1998 Ian Wilmut (1944–) announces the birth of Polly, a transgenic lamb containing human genes.

1998 The World Health Organization (WHO) reports a resurgence in tuberculosis (TB) cases worldwide, with TB killing more people than at any other point in history.

1998 By late 1996, the rate of Sudden Infant Death Syndrome (SIDS) has dropped by 38% following a 1994 launch of a national Back to Sleep Campaign encouraging parents to put their infants to sleep on their backs.

1998 The first element of the International Space Station (the Zarya Control Module or the Functional Cargo Block) is launched.

1999 Pharmaceutical research in Japan leads to the discovery of donepezil (Aricept), the first drug intended to help ward off memory loss in Alzheimer's disease and other age-related dementias.

1999 As the year 2000 approaches, concerns mount about possible deleterious effects of an old computer shortcut that used only the last two digits of a year. Termed the Y2K glitch, considerable investment in programming solutions turns the dawn of 2000 into a worldwide party, but a non-event regarding Y2K fears.

1999 A bright, naked-eye visible nova appears in the constellation Aquila, the Eagle. At its maximum, it was as bright as many of the stars in the constellation, and for a few days, viewers were treated to the spectacle of a new "star" in an otherwise familiar constellation.

1999 A milestone in the human genome project is completed when the first full sequence of an entire chromosome is finished (chromosome 22).

1999 A new atomic clock, which is estimated to neither gain nor lose a second for 20 million years, is started at the National Institute of Standards and Technology.

1999 Astronomers announce the first-ever detection of an entire solar system around a star. Only 44 light-years from Earth, three large planets are found circling the star Upsilon Andromedae, a sun-like star visible to the naked eye on Earth.

1999 Gamma ray burst 990123 is the first to be observed as a visual object in the gamma ray region, giving scientists clues to the structure of the explosion. Even though the object is nine billion light years away, the light is so bright observers on Earth can see it with binoculars.

1999 Population scientists announce that the world's population reaches six billion people.

1999 Scientists at the International Conference on Near-Earth objects adopt the Torino scale, used to portray the threat to Earth of an impact with a particular comet or asteroid.

1999 The World Health Organization (WHO) reports that more than one billion people worldwide smoke, and 3.5 million people are expected to eventually die from causes directly related to tobacco use.

1999 An F-5+ tornado in Oklahoma breaks the record for wind-speed recorded on land at 318 miles per hour.

1999 Scientists at the Institute for Atomic and Molecular Physics determine the precise chemical composition of the paint, glaze, and varnish used by Rembrandt in painting his 1632 masterpiece, "The Anatomy Lesson of Dr. Nicolaes Tulp," providing a restoration team with priceless information about the painting.

1999 A group at Harvard University, utilizing a Bose-Einstein condensate and laser cooling techniques, achieves a temperature of 50 billionths of a degree above absolute zero and, in the process, slows the speed of light from its speed in a vacuum.

1999 Todd Ditmire (1969–) and co-workers create nuclear fusion at Lawrence Livermore National Laboratory by heating clusters of deuterium atoms. At an extremely high temperature, the atom clusters explode and create helium ions.

1999 A nuclear accident at Japan's Tokaimura facility occurs on September 30 when a criticality event, or unplanned chain reaction, exposes 39 workers to radiation contamination and causes the evacuation of families within 1148.2 feet (350 m) of the facility.

1999 End of operations of the Röntgen Satellite (ROSAT), an x-ray (0.1-2 keV) and EUV (0.02-0.3 keV) astronomy mission that is an international collaboration between Germany, the United Kingdom, and the United States.

1999 Launch of a Black Brant V sounding rocket from White Sands, New Mexico, the first to carry a new type of thermal x-ray detector called a quantum calorimeter, or a microcalorimeter.

1999 NASA launches the Far Ultraviolet Spectroscopic Explorer (FUSE): the first in a series of NASA Medium-Class Explorer missions, with objectives to cover the wavelength range between 900 and 1250 Angstroms (90–125 nanometers) and to study the chemical evolution of galaxies.

2000 *Cassini* acquires valuable science data during its flyby of Jupiter, taking many photographs, measuring magnetic fields in collaboration with the Galileo spacecraft orbiting Jupiter, and taking advantage of Jupiter's gravity to boost itself toward Saturn at increased speed.

2000 A modified version of the Jarvik heart (the Jarvik 2000, about the size of a "C" battery) is implanted in a patient as a bridge to transplantation, the first completely artificial heart to be installed.

2000 Forty-two transgenic plants are approved for field trials in the United States, including varieties of cranberries, papayas, potatoes, carrots, cotton, wheat, and ornamental plants.

2000 Food irradiation is endorsed by the United States Food Protection Agency, the American Medical Association, and the World Health Association, and over 40 countries sterilize food by irradiation.

2000 The municipal water supply of Walkerton, Ontario, Canada, is contaminated in the summertime by a strain of the bacterium *Escherichia coli* O157:H7, sickening 2,000 people and killing 7.

2000 After the failure of two NASA Mars probes, NASA revamps its Mars program, delaying plans to retrieve specimens from the planet by almost a decade.

2000 An iceberg, roughly twice the size of Delaware, separates from the Ross Ice Shelf in Antarctica.

2000 Astronomers develop maps that show halos of dark matter distributed throughout the galaxies. Dark matter is the invisible material that makes up 85% of the mass of the universe.

2000 Physicists report possible sightings of the Higgs boson, a subatomic particle that is thought to pass mass on to other particles.

2000 The federal government approves irradiation of raw meat, the only technology known to kill *Escherichia coli* O157 bacteria while preserving the integrity of the meat.

2000 Astronomers discover a galaxy that is 18.6 billion light-years away from Earth. This is the most remote object ever observed. Scientists speculate that this galaxy was formed when the universe was one-sixteenth its present age.

2000 The complete sequence of the plant *Arabidopsis thaliana* is announced in December.

2000 The first volume of *Annual Review of Genomics and Human Genetics* is published. Genomics is defined as the new science dealing with the identification and characterization of genes and their arrangement in chromosomes and human genetics. It is a science devoted to understanding the origin and expression of human individual uniqueness.

2000 Physicists make definitive discovery of the tau particle.

2000 Scientists at the National Institute of Standards and Technology in Boulder, Colorado, force four beryllium ions into a harmonic state called quantum entanglement, a step that may pave the way for the creation of extremely powerful computers based on quantum mechanics.

2001 *American Journal of Psychiatry* publishes studies providing evidence that methamphetamine can cause brain damage that results in slower motor and cognitive functioning—even in users who take the drug for less than a year.

2001 Study entitled *Global Illicit Drug Trends* conducted by the United Nations Office for Drug Control and Crime Prevention (ODCCP), estimates that 14 million people use cocaine worldwide. Although cocaine use leveled off, the United States still maintains the highest levels of cocaine abuse.

2001 The complete draft sequence of the human genome is published. The public sequence data is published in the British journal *Nature* and the Celera sequence is published in the American journal *Science,* giving genetic researchers easy access to specific gene sequences.

2001 U.S. military endorses the situational temporary usefulness of caffeine, recommending it as a safe and effective stimulant for its soldiers in good health.

2001 Letters containing a powdered form of *Bacillus anthracis*, the bacteria that causes anthrax, are mailed by an unknown terrorist or group to government representatives, members of the news media, and others in the United States. More than 20 cases and five deaths are eventually attributed to the attack.

2001 The Chemical and Biological Incident Response Force (CBIRF) sends a 100-member initial response team into the Dirksen Senate Office Building in Washington alongside Environmental Protection Agency (EPA) specialists to detect and remove anthrax. A similar mission was undertaken at the Longworth House Office Building in October, during which time samples were collected from more than 200 office spaces.

2001 A company in suburban Boston announces that a human cell has been cloned to provide stem cells for research. While the experiment was carried on for only a few cell divisions, the technology required to develop a cloned human is a significant advance.

2001 Data gathered by NASA's Hubble Space Telescope and the Chandra X-ray Observatory independently provide strong evidence of an event horizon, the observable boundary region surrounding an unobservable black hole.

2001 In a report published in the international scientific journal *Nature*, researchers report findings that indicate the human genome consists of far fewer genes than previous projected by estimation of phylogenic relationships between humans and other species.

2001 Experiments examining radiation left over from the big bang confirm cosmologists' basic model of how the universe evolved.

2001 Government agencies begin developing joint policies to reduce the huge, seasonal dead zone that occurs in the Gulf of Mexico south of the mouth of the Mississippi River, due in part to overuse of fertilizers.

2001 Heavy-element researchers retract their 1999 claim to having created element 118.

2001 Microbiologists reveal that bacteria possess an internal protein structure similar to that of human cells.

2001 Scientists transform embryonic stem cells into insulin-secreting cells, heart cells, and bone marrow cells.

2001 President George W. Bush announces the United States will allow and support limited forms of stem cell growth and research.

2001 Scientists from the Whitehead Institute announce test results that show patterns of errors in cloned animals that might explain why such animals die early and exhibit a number of developmental problems. The report stimulates new debate on ethical issues related to cloning. In the journal *New Scientist* Ian Wilmut (1944–), the scientist who headed the research team that cloned the sheep "Dolly," argues that the findings argue for "a universal moratorium against copying people."

2001 The International Rice Genome Sequencing Project announces that it will complete the sequence of the *Oryza japonica* rice genome by the end of the year in order to ensure that the sequence data will be accurate and freely available.

2002 A company called DrinkSafe Technology announces the invention of a coaster that can be used to test whether a drink has been drugged by changing color when a drop of the tampered drink is placed on it.

2002 In the aftermath of the September 11, 2001, terrorist attacks on the United States, the United States Government dramatically increases funding to stockpile drugs, vaccines, and other agents that could be used to counter a bioterrorist attack.

2002 The planned destruction of stocks of smallpox causing Variola virus at the two remaining repositories in the U.S. and Russia is delayed over fears that large scale production of vaccine might be needed in the event of a bioterrorist action.

2002 The Defense Advanced Research Projects Agency (DARPA) initiates the Biosensor Technologies program to develop fast, sensitive, automatic technologies for the detection and identification of biological warfare agents.

2002 The Pathogen Genomic Sequencing program is initiated by the Defense Advanced Research Project Agency (DARPA) to focus on characterizing the genetic components of pathogens in order to develop novel diagnostics, treatments, and therapies for the diseases they cause.

2002 A private company, Clonaid, announces the birth of the first cloned human, a seven-pound girl nicknamed Eve. The announcement is discounted by scientists, as Clonaid is funded by a religious sect whose tenants hold that humans were initially cloned from extra-terrestrial visitors to Earth, and no verifiable evidence is presented.

2002 An international group of scientists find a seven million-year-old skull in Chad, called *Sahelanthropus tchadensis*, nicknamed Toumai; initial opinions on whether it is the skull of a hominid or an ancient gorilla are divided.

2002 Astronomers and the International Astronomical Union (IAU) confirm the discovery of an asteroid, designated Asteroid 2002 AA29, in a companion orbit to Earth.

2002 Drought conditions again threaten eastern Africa, with an estimated 15 million people in Ethiopia, 3 million in Kenya, 1.5 million in Eritrea, and 3 million in Sudan facing the risk of starvation as a result.

2002 Evidence convinces many physicists that in addition to matter spinning violently into the vortex of a black hole, the black hole itself rotates like a star.

2002 Reports surface that scaremongering concerning genetically modified foods causes several African countries fighting starvation to reject genetically modified food

supplements that would have reduced starvation and death rates.

2002 Researchers at CERN (Conseil Européé pour la Recherche Nucléaire) produce thousands of antihydrogen atoms cooled to about 50° Kelvin, with the goal of such research to isolate the antihydrogen from ordinary matter long enough to observe its properties.

2002 The International Olympic Committee suspends gender verification procedures for the Olympics in Sydney, Australia, citing potential harm to "women athletes born with relatively rare genetic abnormalities that affect development of the gonads or the expression of secondary sexual characteristics."

2002 An anthropologist finds the skeleton of a Neanderthal baby in the storage area of a French museum, where it had been forgotten for nearly a century.

2002 Chemists synthesize gels for bandages that provide a superior environment for wound healing.

2002 Dietary folate is shown to help avert colon cancer in women, and when taken by mothers during pregnancy, it is shown to reduce the risk of some leukemias in their children.

2002 Jupiter's Great Red Spot, a gigantic 300-year-old storm, collides with the White Oval, a 70-year-old storm roughly the size of Earth, in the planet's upper atmosphere.

2002 Leonardo, a mummified, 77-million-year-old duck-billed dinosaur is unearthed in Montana, complete with minerals remaining from his muscles, beak, skin, and even his last meal.

2002 Scientists find that stockpiled smallpox vaccine doses can be effective if diluted to one-tenth their original concentration, greatly enhancing the number of doses available to respond in the case of an emergency.

2002 Traces of biological and chemical weapon agents are found in Uzbekistan on a military base used by U.S. troops fighting in Afghanistan. Early analysis attributes the source of the contamination to former Soviet Union biological and chemical weapons programs that utilized the base.

2003 The Florida Clean Air Act prohibits smoking in the majority of indoor public places.

2003 Scientists use GIS technology to map the debris field resulting from the break up of the space shuttle *Columbia* upon reentry.

2003 Smart passports fitted with microchips that will allow immigration officials to identify the facial biometric features of the passport holder are proposed.

2003 Almost 500,000 civic and health care workers at strategic hospitals, governmental facilities, and research centers across the United States are slated to receive smallpox immunizations as part of a strategic plan for ready response to a biological attack using the smallpox virus.

2003 Following approximately five deaths by heart attack correlated to individuals receiving the new smallpox vaccine, U.S. health officials at the Centers for Disease Control (CDC) announce a suspension of administration of the new smallpox vaccine to patients with a history of heart disease until the matter can be fully investigated.

2003 In a record sure to be broken, the fastest supercomputer, the NEC Earth-Simulator/5120, executes 36 trillion instructions (elementary computational operations) per second.

2003 Preliminary trials for a malaria vaccine are scheduled to begin in malaria-endemic African areas, where approximately 3,000 children die from the disease every day.

2003 Studies indicate that women with a history of some sexually transmitted diseases, including the human papilloma virus, are at increased risk for developing cervical cancer.

2003 Studies show no correlation between immunization schedules and sudden infant death syndrome (SIDS) occurrences.

2003 X-ray observations from the ROSAT Observatory and NASA's Chandra Ray Observatory allow the identification of high-intensity ultra-bright x-ray sources that many astronomers argue are further evidence of black holes in star-forming galaxies. Although there are other

explanations for these phenomena, the fact that they provide additional confirmation of black holes is enhanced by Hubble observations of stars rotating around stellar cores of these galaxies.

2003 The Human Genome Project for the National Institutes of Health culminates in the completion of the full human genome sequence, published in the journal *Nature.*

2003 The first case of an unusually severe pneumonia occurs in Hanoi, Vietnam, and is identified two days later as Severe Acute Respiratory Syndrome (SARS) by Italian physician and epidemiologist Carlo Urbani (1956–2003), who formally identifies SARS as a unique disease and names it. Urbani later dies of SARS.

2003 SARS cases in Hanoi reach 22, as a simultaneous outbreak of the same disease occurs in Hong Kong. The World Health Organization issues a global alert about a new infectious disease of unknown origin in both Vietnam and Hong Kong.

2003 The World Health Organization (WHO) takes the unusual step of issuing a travel warning that describes SARS as a worldwide health threat. WHO officials announce that SARS cases, and potential cases, had been tracked from China to Singapore, Thailand, Vietnam, Indonesia, Philippines, and Canada.

2003 Canadian scientists at the British Columbia Cancer Agency in Vancouver announce the sequence of the genome of the coronavirus most likely to be the cause of SARS. Within days, scientists at the Centers for Disease Control (CDC) in Atlanta, Georgia, offer a genomic map that confirms more than 99% of the Canadian findings.

2003 By early May, World Health Organization officials have confirmed reports of more than 3,000 cases of SARS from 18 different countries with 111 deaths attributed to the disease. U.S. health officials have reported 193 cases with no deaths. Significantly, all but 20 of the U.S. cases are linked to travel to infected areas, and the other 20 cases are accounted for by secondary transmission from infected patients to family members and health care workers. Health authorities assert that the emergent virus responsible for SARS will remain endemic (part of the natural array of viruses) in many regions of China well after the current outbreak is resolved.

2003 The *Galileo* spacecraft enters into Jupiter's atmosphere, where it is destroyed following a highly successful mission. This maneuver was designed to eliminate any chance that *Galileo* would, if left in orbit in the Jovian system, impact the Jovian moon Europa, which has a subsurface ocean that is considered a possible site for extraterrestrial life, and hence a site to be protected.

2003 China launches the *Shenzhou-5* spacecraft into Earth's orbit with astronaut Yang Liwei (1965–) aboard, making China the third country to join the ranks with manned space programs. Yang orbited Earth 14 times before safely landing in north China the next day.

2003 The British-built *Beagle 2* space probe attempts a scheduled landing on the planet Mars and loses communication with scientists at the European Space Agency.

2003 The first case of bovine spongiform encephalopathy (BSE, mad cow disease) in the Unites States is found in a cow in Washington state. Investigations later reveal that the cow was imported from a Canadian herd that included North America's first "home-grown" case of BSE six months earlier.

2004 National Institute of Aging long-term study links diabetes mellitus with a 65% increased risk of developing Alzheimer's disease. These results are among the first to examine how certain cognitive systems, including memory for words and events, and the speed of processing information decline in people with diabetes, while others do not.

2004 National Institutes of Health (NIH) proposes to enhance public access to taxpayer-supported research by creating an online, searchable archive of all NIH-funded publications within 6 months of their appearance in journals.

2004 The Food and Drug Administration bans dietary supplements containing ephedrine.

2004 Project BioShield Act of 2004 authorizes U.S. government agencies to expedite procedures related to rapid distribution of treatments as countermeasures to chemical, biological, and nuclear attack.

2004 Russia ratifies the Kyoto treaty, putting it into effect worldwide even without U.S. ratification.

2004 Scientists discover that a single protein, known as mBDNF, appears central to the formation of long-term memories.

2004 Anabolic Steroid Control Act of 2004 bans over-the-counter steroid precursors.

2004 Based on recent results from controlled clinical studies indicating that Cox-2 selective agents may be connected to an elevated risk of serious cardiovascular events, including heart attack and stroke, the Food and Drug Administration issues a public health advisory urging health professionals to limit the use of these drugs.

2004 The International Human Genome Sequencing Consortium publishes its scientific description of the finished human genome sequence, reducing the estimated number of human protein-coding genes from 35,000 to only 20,000–25,000, a surprisingly low number for the human species.

2004 An international clinical trial recommends letrozole after 5 years of tamoxifen treatment to continue to reduce the risk of recurrence of breast cancer in women. This advance in breast cancer treatment interrupts the progression of cancer by using a drug that blocks a crucial metabolic pathway in the tumor cell.

2004 Chinese health officials in the Guangdong province of China launch a mass slaughter of civet cats, a cousin of the mongoose considered a delicacy and thought to be a vector of SARS, in an attempt to control the spread of the disease.

2004 World Wildlife Fund scientists announce that the world's orangutan population decreased by half in the 1990s, and with more than 60% of the great apes still living in unprotected areas, extinction of the two orangutan species is probable by the year 2025 unless a dramatic commitment to habitat preservation is undertaken.

2004 California bans the gasoline additive MTBE. Ethanol becomes the new additive of choice, although it can increase air pollution.

2004 A 35-year-old television producer in the Guangdong province of China is the first person to become ill with SARS since the end of the May 2003 initial outbreak of the newly-identified disease. Within two weeks, three other persons are suspected of having SARS in the region, and teams from the World Health Organization return to investigate possible human-to-human, animal-to-human, and environmental sources of transmission of the disease.

2004 NASA's *Stardust* space probe has a close encounter with Comet Wild-2, passing just 149.1 miles (240 km) away from the comet, returning dramatic images of its icy surface and collecting sample particles for return to Earth.

2004 NASA's *Spirit* space probe, designed to search for signs of water on Mars, lands successfully on the red planet, and begins returning data and pictures to NASA scientists within hours of touchdown.

2004 High levels of toxins are found in farmed salmon, according to the journal *Science.*

2004 NASA successfully lands the *Spirit* and *Opportunity* rovers, mobile geology labs on the surface of Mars. *Opportunity* soon afterwards discovers evidence that water had once occupied its landing site, increasing the possibility that the necessary ingredients for life may have once existed on Mars.

2004 Scientists claim to create a sixth form of matter, called a fermionic condensate, and predict it can lead to the next generation of superconductors. Other known forms of matter are gases, solids, liquids, plasma, and a Bose-Einstein condensate created in 1995.

2004 The Women's Health Initiative (WHI) study, a large, multi-center prevention

study of estrogen-alone hormone therapy in healthy postmenopausal women without a uterus is stopped in February, after researchers find that estrogen-alone had no effect on coronary heart disease risk, but increased the risk of stroke. The study also finds that estrogen-alone therapy significantly increased the risk of deep vein thrombosis, had no significant effect on the risk of breast or colorectal cancer, but reduced the risk of hip and other fractures. In addition, among older women in the study, estrogen-alone therapy did not prevent cognitive decline.

2004 An ivory-billed woodpecker, the first seen since 1944 and considered extinct, is reported in the Cache River National Wildlife Refuge of Arkansas. A large irrigation project there designed to provide water for rice farming is halted until there is further study of its potential impact on the bird's habitat.

2004 Scientists report the synthesis of new elements 113, Ununtrium, and 115, Ununpentium.

2004 A 343.5 gallon (13,000 l) fuel spill in New Zealand's Milford Sound fjord, a World Heritage site, is characterized as "eco-terrorism and economic sabotage" against the country's lucrative tourism industry.

2004 A joint advisory by the Food and Drug Administration and Environmental Protection Agency suggests limiting consumption of tuna and certain other fish by children and women of childbearing age, after findings show low levels of mercury contamination. Coal-fired power plants are suspected to release into lakes and streams up to half of the mercury that eventually makes its way into oceans and contaminates fish.

2004 Scientists report that Earth could be experiencing its sixth large extinction event, which began about 50,000 years ago, after studies show extinctions among populations in all main ecosystems in the United Kingdom.

2004 Australia's parliament passes a law that includes a fishing ban on one third of the Great Barrier Reef, making it the most protected reef system on Earth.

2004 The Environmental Protection Agency instructs 31 states to clean up soot and smog-plagued regions.

2004 A federal commission reports that oceans of the United States are in dire shape from pollution and overfishing.

2004 The Dian Fossey fund reports a 70% drop in the lowland gorilla population in eastern Congo due to human warfare.

2004 Scientists report that falling cod stocks could be wiped out completely by 2020 if the current rate of overfishing continues.

2004 Amid the worst drought in over 100 years, Australian scientists warn that the continent faces an environmental crisis unless scarce water resources in the world's most arid inhabited continent are carefully managed.

2004 A United Nations report warns that the Aral Sea, once one of the world's largest inland bodies of water, could dry up unless its bordering countries work to increase its water supply.

2004 Stephen Hawking (1942–) surmises that black holes form an apparent horizon from which information can eventually escape. These findings contradict his earlier work on black holes, and lose him a bet made with two colleagues at the California Institute of Technology in 1991.

2004 NASA launches the MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) interplanetary probe, designed to orbit and study Mercury in 2011.

2004 Thailand health officials report one instance of probable human-to-human transmission of H5N1 strain Avian flu.

2004 Americans David J. Gross (1941–), H. David Politzer (1949–) and Frank Wilczek (1951–) win the Nobel Prize in physics for their explanation of the force that binds particles inside the atomic nucleus. Their theory of quantum chromodynamics explains how quarks behave.

2004 American Irwin Rose (1926–) and Israelis Aaron Ciechanover (1947–) and Avram

Hershko (1937–) win the Nobel Prize in chemistry for discovering a way for cells to destroy unwanted proteins.

2004 Wangari Maathai (1940–) of Kenya wins the Nobel Peace Prize, after campaigning against government oppression and environmental policies.

2004 1,856 of 5,743 species of amphibians are "globally threatened," according to the journal *Science.*

2004 A comprehensive scientific study of the Arctic climate confirms that Arctic ice is melting at a growing rate.

2004 Scientists track an algae bloom covering 400 square miles (643.7 sq km) in the waters off the Gulf Coast that causes a mass fish kill and dolphin deaths near Florida.

2004 On December 26, the most powerful earthquake in more than 40 years occurs off the Indonesian island of Sumatra; a resulting tsunami produces a disaster of unprecedented proportion in the modern era, with the International Red Cross estimating the death toll at over 150,000 lives.

2005 A massive 7.6-magnitude earthquake leaves more than 3 million homeless and without food and basic medical supplies in the Kashmir mountains between India and Pakistan. 80,000 people die.

2005 H5N1 virus, responsible for avian flu, moves from Asia to Europe, as it is found in wild ducks in Romania. The World Health Organization attempts to coordinate multinational disaster and containment plans. Some nations begin to stockpile antiviral drugs.

2005 Hurricane Katrina slams into the U.S. Gulf Coast, causing levee breaks and massive flooding to New Orleans, as well as extensive damage to the coasts of Louisiana, Mississippi, and Alabama. Federal Emergency Management Agency (FEMA) is widely criticized for a lack of coordination in relief efforts. Three other major hurricanes make landfall in the United States within a two-year period, stressing relief and medical supply efforts. Long-term heath studies begin of populations in devastated areas.

2005 Korean scientist Woo Suk Hwang's (1953–) claims to have cloned human stem cells lines are proved fraudulent. Despite this setback, the potential for therapeutic cloning for medical purposes continues unabated.

2005 The World Health Organization reports outbreaks of plague in the Democratic Republic of Congo.

2005 The Food and Drug Administration Drug Safety Board is founded.

2005 NASA's Stardust mission successfully navigates through the cloud of ice and dust surrounding the center of comet Wild 2, returning detailed images of a comet.

2005 NASA launches *Deep Impact*, part of which crashed into the surface of comet Temple 1 and provided scientists with the most up-close data and images of a comet in the history of space exploration.

2005 NASA's *Cassini* spacecraft and the European Space Agency's Huygens probe is released into the atmosphere of Saturn's largest moon, Titan. It is discovered that Titan has evidence of methane rain, erosion, stream-like drainage channels, dry lakebeds, volcanism, and very few craters.

2005 Thousands of wild migratory birds, infected with H5NI strain Avian flu, die near Qinhai Lake (located in central China). Viruses subsequently detected in countries along traditional wild bird migratory routes are found to be genetically identical to the virus causing the deaths at Qinhai Lake.

2005 Brookhaven National Laboratory reports evidence that indicates the creation of a quark-gluon plasma, a form of matter that last existed moments after the big bang.

2005 NASA announces that the *Voyager 1* spacecraft, the most distant artificial object from Earth, has traveled 8.7 billion miles from the sun, crossing outside the termination shock and entering the heliosheath.

2005 Space Shuttle *Discovery* (STS-114) launches successfully into orbit, marking NASA's first return to human space flight since the *Columbia* accident in 2003. *Discovery* safely returns to Earth on August 9, 2005.

2005 *Mars Reconnaissance Orbiter (MRO)* launches from Cape Canaveral, Florida, on its way to scrutinize the physical features of Mars, including its atmosphere and its subterranean layers.

2005 Australian scientists estimate that cyclone Ingrid, which lashed northeastern Australia, damaged 10% of the Great Barrier Reef.

2005 An aerial survey estimates the hippopotamus population in northeastern Congo's Virunga National Park is down to less than 1,000 animals, compared to 29,000 in 1974.

2005 The United Nations reports that the hole in the ozone layer above Antarctica has grown to near record size, suggesting 20 years of attempted pollution controls have so far had little effect.

2005 The European Project for Ice Coring in Antarctica reports that carbon dioxide in the current atmosphere is greater than at any time during the last 650,000 years.

2006 Scientists report that as many as 112 species of frogs have disappeared since 1980, as well as some 65 amphibian species in Central and South America. Global warming is suspected as the cause.

2006 Astronomers reclassify the asteroid Ceres, first classified as a planet when discovered in the 1800s, along with Eris (previously nicknamed Xena), as dwarf planets.

2006 The European Union bans the importation of avian feathers (non-treated feathers) from countries neighboring or close to Turkey.

2006 Human trials begin for vaginal microbicide gels designed to protect women from HIV.

2006 John Mather (1946–), of NASA's Goddard Space Flight Center, receives the 2006 Nobel Prize for Physics (with University of California's George Smoot [1945–]) for his work on cosmic microwave background radiation. It is the first Nobel for a NASA civil servant.

2006 Mad cow disease is confirmed in an Alabama cow as the third reported case in the United States.

2006 More than a dozen people are diagnosed with avian flu in Turkey, but UN health experts assure the public that human-to-human transmission is still rare and only suspected in a few cases in Asia.

2006 Norway announces plans to build a "doomsday vault" in a mountain close to the North Pole that will house a two-million-crop seed bank in the event of catastrophic climate change, nuclear war, or rising sea levels.

2006 The International Astronomical Union (IAU) votes on the definition of the term planet, identifying necessary criteria for the definition. To be classified as a planet: (1) The object must be in orbit around a star, but must not be a star itself, (2) the body's own gravity must pull it into a nearly spherical shape, and (3) the body has cleared the area around its orbit.

2006 Pluto is demoted from planet status and reclassified by astronomers as a dwarf planet, based upon the new definition for a planet adopted by the International Astronomical Union.

2006 A temporary halt in exporting caviar around the world is made by the United Nations Convention on International Trade in Endangered Species in order to compel nations to show that their fishing practices are sustainable and not a continuing threat to the sturgeon population.

2006 *Stardust* capsule lands in the Utah desert and returns samples of interstellar dust that could offer vital clues about the origins of the solar system.

2006 At an international conference in Beijing, China, donors pledge $1.9 billion to counter the spread of H5N1 strain avian flu (bird flu).

2006 NASA launches *New Horizons*, the first spacecraft designed to visit Pluto, from Cape Canaveral, beginning its nine-year voyage toward Pluto and the Kuiper Belt.

2006 Commercial fishing in Australia is banned in Sydney harbor due to dangerous levels of poisonous dioxin detected in shrimp and fish.

2006 Dozens of new species of frogs, butterflies, and plants, as well as mammals hunted to near extinction elsewhere, are discovered in an isolated Indonesian jungle.

2006 French health officials confirm finding H5N1 (avian flu) at a farm where thousands of turkeys died. This is the first case found in farm birds in the European Union.

2006 NASA research shows that the Antarctic ice sheet melting has raised global sea level by 0.05 inches (1.2 mm) since 2002.

2006 UK health officials report the first case of H5N1 (avian flu) in Britain as the H5N1 virus is found in a dead swan in Scotland.

2006 NASA launches two satellites designed to provide the first 3-D views of Earth's clouds and help predict how cloud cover contributes to global warming.

2006 China's official news agency reports that glaciers in the Qinghai-Tibet plateau, also known as the "roof of the world," are melting at a rate of 7% annually due to global warming.

2006 36,750 square miles (59,143 km) in the Bering Sea and Gulf of Alaska are designated as critical habitat for right whales.

2006 NASA satellite data shows Greenland's ice sheet is melting at a rate that exceeds scientists' estimates.

2006 The World Health Organization declares support for using DDT indoors to control mosquitoes in regions where malaria has a stronghold.

2006 In an effort to aid vaccine development, WHO influenza pandemic task force officials ask that all countries to share H5N1 (avian flu) virus samples and genetic sequencing results.

2006 Researchers report that Earth's temperature has been warming by 0.3° F per year for the last three decades, and is at a current 12,000-year high.

2006 Researchers report that carbon dioxide from industrial emissions is raising the acidity of the world's oceans, threatening plankton and other organisms that form the base of the entire marine food web.

2007 State media reports that China will have a gender imbalance that includes 30 million more men of marriageable age than women in less than 15 years due to the country's one-child policy.

2007 Scientists warn that glaciers could all but disappear from the European Alps by 2050, and that most would be gone by 2037.

2007 In London, airline tycoon Richard Branson (1950–) announces a $25 million prize for the first person to devise a way of removing greenhouse gases from the atmosphere.

2007 Scientists report a way to stop a fungus partially responsible for the extinction of up to 170 species of the world's frogs in the past decade.

2007 The World Wildlife Fund conservation group states that climate change, pollution, over extraction of water, and encroaching development are killing some of the world's major rivers, including China's Yangtze, India's Ganges, and Africa's Nile.

2007 Scientists report that although Britain once had 25 native species of bumblebee, three species have been wiped out in the past 50 years and 10 more are now severely threatened.

2007 The United Nations reports that air pollution contributes to the premature death of over 400,000 Chinese each year, and that 16 of the most polluted cities in the world are in China.

2007 The journal *Science* reports that the crucial "carbon sink" that holds 15% of the world's excess carbon dioxide, Antarctica's Southern Ocean, is nearing saturation and could soon be unable to absorb more.

2007 In an effort to promote ecotourism and nature studies, Russia establishes the Zov Tigra National Park to protect Siberian tigers.

2007 World leaders at a G8 summit agree to "seriously consider" proposals to cut the emissions of greenhouse gases by 50% by 2050.

2007 Scientists find a compound, periostin, derived from skin around bone, that stimulates the growth of new heart cells, potentially leading to new treatments for humans to replace tissue damaged during a heart attack.

2007 Researchers from the University of North Carolina in Chapel Hill report that coral reefs in the Indo-Pacific, an area stretching from the Sumatra island to French Polynesia, dropped 20% since 1985 due largely to climate change and coastal development.

2007 Intel corporation has a breakthrough that will allow dramatic size reductions in microprocessors by using the element hafnium and new metal alloys.

2007 Researchers at the Pierre Auger Observatory in Argentina provide evidence that high energy cosmic particles (including protons) that impact Earth originate from regions near the black holes at the center of some galaxies (active galactic nuclei). Although the exact mechanisms are not yet fully understood, researchers calculate that the protons are accelerated to levels hundreds of millions time greater than reachable by the largest and most powerful Earth-based particle accelerators.

2007 Astronomers from the University of Texas and University of California, Berkeley, confirm the 2006 observation of the largest and brightest stellar explosion, or supernova, observed to date. The explosion was of a star approximately 100 to 200 times the size of Earth's sun.

2007 Student protests at Staunton River High School in Bedford, Virginia, lead to temporary closing of the school for cleaning, along with 20 others in the area, after senior student Ashton Bonds dies in a local hospital from multiple-resistant *Staphylococcus aureas* (MRSA) infection. Within days, seven other states report students with MRSA infections, including three deaths. As media attention grows and classrooms are disinfected, the Center for Disease Control and Prevention (CDC) reports that community-acquired MRSA infections probably occur about twice as often as previously thought, and that overall, MRSA infections are responsible for more deaths in the United States each year than AIDS.

2007 The fourth IPCC report is issued (the first segment in February, and the last in November). The Intergovernmental Panel on Climate Change (IPCC) Scientists, composed of scientists from 113 countries, issues a consensus report stating that global warming is caused by man, and predicting that warmer temperatures and rises in sea level will continue for centuries, no matter how much humans control their pollution.

2007 University of Copenhagen in Denmark professor Henrik Clausen announces in the journal *Nature Biotechnology* the discovery of enzymes (proteins that help control the rates of reaction) and a method to convert any blood type into the universal Type O, a discovery that could lead to reduction in blood shortages.

2007 Researchers announce that recent analysis of residual radioactivity in skeletal remains found near Hofmeyr, South Africa, in 1952 provides evidence that humans migrated from Africa between 65,000 and 25,000 years ago.

2007 In August 2007, a month before annual Arctic sea-ice melting normally peaks, a new record was already established for shrinkage of the north polar ice cap. No summer since 1979, when satellites first allowed accurate tracking of the annual melting, recorded such a large loss of ice. William Chapman, an expert at the University of Illinois, Urbana-Champaign, said that the melting rate in June and July of 2007 was "simply incredible." Arctic sea-ice melting is predicted to have many impacts, including increased Arctic regional temperatures, increased Arctic coastal erosion, declines in polar bear populations, damage to traditional hunting practices of indigenous Arctic peoples, and disruption of large-scale ocean circulations.

2007 Increased extreme weather is predicted as a consequence of global climate change. In August 2007, scientists at the World Meteorological Organization, an agency of the United Nations, announced that during the first half of 2007, Earth showed significant increases above long term global averages in both high temperatures and frequency of extreme weather events

(including heavy rainfalls, cyclones, and wind storms). Global average land temperatures for January and April of 2007 were the warmest recorded for those two months since records began in 1880.

2007 In Algeria, an international conference on desertification closed with a call (dubbed the Algiers Appeal) to all African countries to ratify the Kyoto Protocol in an effort to help slow the rapid expansion of deserts on the continent.

2007 Satellite lasers detect previously undiscovered lakes under Antarctic glacial ice. The lakes exhibit high rates of flow (filling and draining).

2007 Anthropologists working in Senegal report observations of female chimpanzees manufacturing spears from tree branches that they then use to hunt small mammals.

2007 An Antarctic undersea expedition discovers new species that live on the sea floor beneath collapsed ice sheets.

2007 A team of researchers at Imperial College of London induces stem cells derived from bone marrow to form functioning human heart-valve tissue.

2007 In October, Welsh researchers discover what was thought to be the world's oldest living animal, a 400-year-old clam *Arctica Atlantica*. Researchers determine the clam's age from ring patterns on its shell.

2007 In October, British scientists with the Wide Area Search for Planets (WASP) announce the discovery of three Jupiter-sized exoplanets outside our own solar system.

2007 A group of U.S.-based researchers announce a major step toward the synthetic creation of life when they publish work in the journal *Science* showing that they synthetically engineered the construction of the genome (the entire set of genes) of a common laboratory bacterium from the elemental building blocks of DNA molecules.

2007 The area of ocean covered by ice around the North Pole varies seasonally, reaching a minimum every September. In August and September 2007, the north polar sea-ice cap shrank to the smallest size ever recorded. As of September 16, U.S. government scientists announced, the ice was 1.59 million square miles (4.14 million square kilometers) in size, about a fifth smaller than the previous record, set in September 2005. The Northwest Passage, which is the sea route from the Atlantic to the Pacific along the northern edge of North America, was ice-free for the first time in recorded history. Surprised and concerned by the extent of the 2007 melting, climate scientists predict increased melting of the ice due to global climate change. Thus far, Arctic temperatures have warmed twice as fast as the rest of the world.

2007 Former U.S. Vice President Al Gore (1948–) and the IPCC share the 2007 Nobel Peace Prize for raising public awareness about global warming and climate change and for establishing the foundations to begin to solve the problem. Gore's film about climate change and global warming, *An Inconvenient Truth*, also wins major film awards.

2007 The largest driver of global climate change is carbon dioxide (CO_2) in the atmosphere, which is directly increased by the burning of fossil fuels. In October 2007 scientists announce that CO_2 levels increased since 2000 faster than even the most pessimistic predicted forecasts of the late 1990s. Growth in atmospheric CO_2 was only 1.1% per year for 1990–1999, but accelerated sharply to more than 3% per year for 2000–2004. Climate scientists attribute most of the increased emissions to increases in human population and industrial activity.

2007 In its 2007 Red List of Threatened Species, the World Conservation Union estimates that about 200 endangered species moved closer to extinction during the year and listed more than 40,000 species on its endangered list.

2007 Stem cells are undifferentiated cells that can give rise to diverse types of differentiated (specialized) cells. Studies announced in 2007 show the ability to create stem cells from cloned monkey embryos and normal adult skin cells rather than from destroyed

human embryos may offer a potential solution to ethical concerns about the origins of stem cells.

2007 In December, Australia's new Prime Minister reverses the prior government's policy and ratifies the Kyoto Protocol. The action by Australia isolates the United States as the only (and largest) industrialized nation not to ratify the agreement to limit greenhouse gas emissions.

2008 In January, an article in *Nature Geoscience* reports that Antarctica is definitely losing ice overall, and losing it an accelerating pace. Ice loss is near zero in East Antarctica, but in the West Antarctic Peninsula, ice loss increased from 1996 to 2006 by 140%, to about 66.1 billion Imperial tons (60 billion metric tons) per year, and in the rest of West Antarctica it increased by 59%, to about 145.5 billiion Imperial tons (132 billion metric tons) per year. Most of the increased loss is happening in channels along which glaciers flow to the sea; as ocean currents are changed by global warming, they shrink the parts of the glaciers protruding into the sea, in effect uncorking the glaciers. According to the new figures, Antarctica is now losing ice almost as fast as Greenland.

2008 Computer models of global climate change predict that East Antarctica will gain ice as snowfall increases, while West Antarctica will lose ice as melting accelerates. Both effects have been observed. If Antarctica loses more ice than it gains, it contributes to sea-level rise; if the reverse, it slows sea-level rise. Not until 2008 did climatologists know whether gain or loss was dominant.

2008 The UN's Intergovernmental Panel on Climate Change announces in January that its next report would study the possibility of accelerated melting of both the Greenland and Antarctic ice shelves, which could cause several meters of sea-level rise by the end of this century.

2008 At the Royal Astronomical Society's National Astronomy Meeting, astronomers from St. Andrews University announce the discovery of a planetary system about five thousand light years away that is similar to regions of Earth's solar system. Using micro-lensing techniques, they discover a system that orbits a star about half the size of Earth's sun. The discovery fuels speculation among astronomers that the discovery of systems that could contain Earth-like terrestrial planets was imminent. As of early 2008 more than 300 extrasolar planets (exoplanets) were identified, but none yet approximating Earth conditions.

2008 Ongoing research confirms that global sea level—the average height of the ocean's surface apart from the daily changes of the tides—is rising. Sea level rise threatens fresh water supplies, coastal land use, and vital economic activity. For some islands, significant sea level rise could be devastating.

2008 Sexually transmitted diseases (STDs) are a global problem, but a recent National Health and Nutrition Examination Survey released by the U.S. Centers for Disease Control and Prevention (CDC) also warns that approximately one in four teenage girls in the United States may have contracted a STD.

2008 Oil and food prices rise sharply on a global scale, increasing dangers of famine and poverty. Critics contend increased prices for petroleum lead to the diversion of food crops to biofuel production.

2008 Global agricultural experts issue a warning that UG99, a plant rust fungus that kills to up to 80% of current wheat strains, threatens crops (most immediately those in developing countries). The spread of UG99 raises the specter of widespread wheat crop destruction on a global scale. Such destruction would, of course, result in massive poverty for farmers, widespread economic damage, increased global wheat prices (at a time when wheat prices have already experienced sharp increases), and possible famine.

2008 China overtakes the United States as the world's largest emitter of greenhouse gases.

2008 Yellow fever is an acute viral disease that is spread by mosquitoes and that occurs in Africa and South America. Although a vaccine is available to prevent the disease, World Health Organization and public health officials announce that the incidence of yellow fever is growing, especially in South America.

2008 Dengue fever, a mosquito-borne viral disease that causes severe muscle and joint pain, reached epidemic proportions in areas of Brazil in April 2008. In tropical cities, crowded conditions with little sanitation infrastructure can lead to an outbreak of dengue fever during the rainy season.

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